Making Things Up: Workshop Practice as a Place of Design

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Making Things Up: Workshop Practice as a Place of Design

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Abstract

This thesis considers workshop practice, specifically the production of three-dimensional prototype products, as a place of design. I study techniques used to make emergent artefacts, in an effort to better understand how they structure design practice.

I begin by presenting an argument that recasts the making process as a means of thinking, rather than merely transcribing antecedent ideas. I draw on literature from disciplines where this argument has been well-rehearsed, and contribute a novel synthesis of existing ideas in terms relevant to design studies and practice. This provides a theoretical foundation from which I can understand techniques as means of both *doing things to the world*, and *finding out how those things are going*.

I then introduce the term *epistemic character* in order to frame a new subject of interest – how techniques structure design processes. I argue that we may investigate the epistemic character of techniques, and I provide examples of how such investigations may be pursued. To this end, I combine my interdisciplinary literature review with first-hand studies of designing and making techniques. With reference to these studies, I describe three questions that may be asked to interrogate epistemic character: What are the *questions posed* by a technique?; What is its *step-character*?; and what is the *nature of the emergent result*?

I end with a discussion of how these features of epistemic character influence the distribution of decision making throughout design processes. I suggest there is an important distinction to be made, between processes throughout which things emerge step-by-step, and processes in which things are planned in advance of their execution.

The thesis provides design and craft theory with a novel and useful insight into how practitioners might think through making.

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All figures drawn by Philip Luscombe. Where figures are redrawn versions of other work, attribution is made in the text.

Chapter 6

Acknowledgements

Many, many thanks to Jayne Wallace, Emma and my colleagues
in the Design Department of Northumbria University.

Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others. Any ethical clearance for the research presented in this thesis has been approved. Papers in which parts of this thesis have been previously published are included in the ‘Accompanying Material’ section.

I declare that the word count of this thesis is 70,108

Name:

Signature:

Date:

1. Introduction

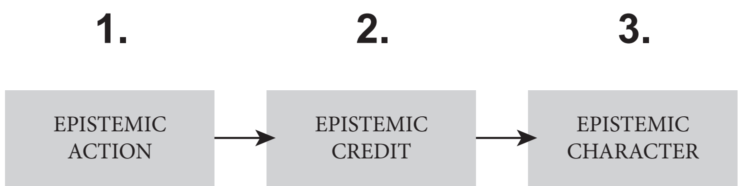
This thesis considers workshop practice, specifically the production of three-dimensional prototype products, as a place of design. The ambition of the research is to better understand how the techniques of making—including sawing, measuring, cutting, carving, assembling and more—structure design practice. As design practitioners or craftspeople manipulate an emergent artefact, how do the techniques they are using influence the process of working things out and, ultimately, their results?

All this is to presume that the techniques used to make emergent artefacts *do* structure design practice in some way. As I describe in Chapters 2 and 3, however, this is to take a position on the relationship of "designing" and "making" that is not well represented in existing design theory. In fact, if we subscribe to a typical definition of design as the capacity to think *before* we act (see 3.1), we might be left wondering what possible part techniques could play in cognitive processes. On this understanding, making techniques are the means by which to realise pre-existing ideas. Their role is that of a translator, rather than an interlocutor. And, whilst we may describe the risk or certainty with which they can arrive at a pre-determined destination, there is little else to be said about the influence of techniques. My thesis, however, suggests otherwise.

In this chapter, I introduce the structure of the thesis, by giving a brief synopsis of each subsequent chapter. A more comprehensive introduction to the themes of the study, and their development, is presented throughout Chapters 2 and 3. Before presenting the synopsis, however, I give an even briefer account of the ideas to come. I suggest the whole thesis can be understood through a narrative of three ideas.

1.1. The Thesis in Three Ideas

Figure 1. 1 The thesis in three ideas



As seen in Figure 1.1, the three ideas that summarise this thesis all relate to the "epistemic" nature of practice. They are all concerned with *working things out.*

Epistemic actions are those taken to aid cognition (Kirsh and Maglio 1994) (see 3.2.2 and 4.2). They do not change the world in order to move us towards a goal, but to help us think. An example can be found in the assembly of a jigsaw. We do not sit staring at the pieces and solve the puzzle *in our heads.* We pick bits up, spin them around and try them for fit. These are epistemic actions.

From this follows the idea of *epistemic credit.* If we recognise that things in the world can be used as a means of thought, we can treat them as parts of cognitive systems (Clark and Chalmers 1998) (see 3.2.2). On this understanding, we can study techniques as more than just a way to realise pre-existing ideas. They become active systems of thought.

The last of the three ideas builds on the other two. It is my thesis' main contribution: I introduce the term *epistemic character*. I define epistemic character as a property of techniques. It describes the ways in which a technique structures the process of working things out. I present a discussion of how we may interrogate the epistemic character of techniques, and I explore the influence this character has on design practice.

Whilst lacking in detail, this basic three-idea structure maps onto the development of my study, and this thesis as a whole. The following chapters flesh out the the idea of epistemic character. In Chapters 4, 5, 6 and 7 I present the subtleties of this contribution, thus providing design and craft theory with a novel and useful insight into how practitioners might think through making.

1.2. Outline of Chapters

Chapter 2. Methods and Chronology

In the following chapter, I introduce the inspirations for the study and describe how it has been conducted. I trace the development of the theoretical grounding, methodology and findings of the research. Alongside this chronology, I also detail my two research methods: an interdisciplinary review of literature and first-hand studies of techniques.

Chapter 3. Designing and Making

Chapter 3 expands the theoretical foundation introduced in Chapter 2. It is an interdisciplinary literature review, focused on the relationship between "designing" and "making". I start by reflecting on the historic division of these two aspects of production in design literature. Taking inspiration from the fields of archaeology, anthropology, cognitive science and philosophy, I argue that the assumptions of design theory can be aligned with a more general dualism of "thought" and "action". Alternative positions in these disciplines promote “extended”, “materially-engaged”, and “distributed” models of cognition. I suggest these enable a richer understanding of a practitioner’s engagement with materials, tools and techniques.

The key idea explored in this chapter is that thinking doesn’t just happen “in the head”, but occurs between people and things. I suggest that this concept sheds new light on the relationship between designing and making, and offers a valuable perspective from which to interrogate the influence of making techniques on design practice.

<u>Chapter 4. Making and Thinking</u>

Where Chapter 3 takes a broad, interdisciplinary approach to defining my theoretical commitments, Chapter 4 begins to apply these ideas in a more focussed critique of design and making practice. I present a criticism of the work of design theorist David Pye. I use Pye’s work as an exemplar of the assumptions made by linear models of thought and action. This, I suggest, is at odds with the alternative models of cognition presented in Chapter 3.

This critique is presented alongside the thesis’ first practical study—an investigation of hammer use. With reference to the concept of epistemic action, I use the example of hammering a pin to develop an account of tool use as simultaneously *epistemic* and *pragmatic*. That is to say, I claim techniques are at once for doing things, and for finding out how those things are going. This lays the foundation for the subsequent studies of epistemic character.

<u>Chapter 5. The Epistemic Character of Techniques</u>

In Chapter 5, I explore what I mean by *epistemic character.* Although I introduce a working definition at the end of Chapter 2 (2.6.14), the studies of practice presented here are an opportunity to examine the idea in detail. To this end, I present three questions that may be asked of a technique’s epistemic character: what are the *questions posed* by the technique?; what is its *step-character*?; and, what is the *nature of the emergent result*? I explore each of these questions with respect to particular techniques. Through first-hand studies, I investigate the use of rulers and dividers as measurement tools, the process of carving a wooden spoon, and the design and construction of paper aeroplanes.

<u>Chapter 6. Making Things Up</u>

Chapter 6 discusses how the epistemic character of techniques may support, or potentially compromise, design processes. The main theme of the discussion centres on the subject of how techniques distribute decision making throughout a process. This is an idea that combines the interests both of the theoretical foundation of the research, and the subsequent descriptions of practice. It takes influence from the claims made in Chapters 3 and 4 about how we use the world to support cognition, and applies them to a suggestion of how we should aspire to utilise techniques throughout design processes.

Drawing on a range of practical examples (including sawing, hammering, filing and planing), I suggest that we may make a distinction between processes throughout which things emerge step-by-step, and processes in which things are planned in advance of their execution.

I also move from localised studies of tool use, to a macro-level perspective, in a study of techniques used for prototyping furniture. Here I aim to demonstrate how the idea of epistemic character can be applied in a wider context.

Chapter 7. Discussion

In Chapter 7, I restate the contributions summarised below (see 1.3), and identify where I believe they have been made throughout the thesis. I then go on to present a further "discursive contribution", which builds on the ideas of Chapter 6 in a more speculative (and potentially contentious) spirit. I explore the idea that the epistemic character of techniques might have a significant effect on the quality of our environment. On this, I take my lead from architect Christopher Alexander and his work on the importance of step-by-step processes.

1.3. The Structure of The Thesis

As described in the outline above, the chapters of this thesis are themed and arranged using a non-typical approach. A more standard presentation might see a sequence of chapters such as 'literature review'; 'methodology'; 'data gathering'; 'data analysis'; and 'discussion'. The alternative approach here has been taken for two reasons. Firstly, it is a reflection of the methodology of the research, wherein the relationship between literature review and first-hand studies of techniques has been ongoing throughout (see 2.3 and 2.6.7). Between these two methods of enquiry, writing has been a means not just to record 'findings', but a vital way of forming the ideas and contributions themselves. The writing of this thesis has been simultaneously a method and the result of the research—it is only through writing drafts of the subsequent chapters that their content has been developed, and the implications of my argument have become clear. To adopt a sequence of chapters that suggests a distinction between literature review and my sources of 'data' would, therefore, seem at odds with how the research was conducted.

The second reason for the interwoven structure is that it is intended to strengthen the legibility and clarity of the thesis' main arguments. In Chapter 4, for example, I combine a discussion of hammer use with a critique of David Pye's work and the concept of epistemic action (see 4.2). I do this to suggest the failings of a wholly pragmatic understanding of tool use. In the more typical thesis structure described above, it might have been possible to present the critique of Pye's work separately from my description of hammer use. I could have detailed hammer use independently, as "data" that could subsequently be analysed with reference to Pye's ideas. My practice-based studies of tool use would thus have become disentangled from the line of argument—they would have been documented as "raw" data. The decision to instead describe occasions of tool use alongside ideas from the literature has provided a means of developing an argument incrementally, with continual reference to practice. I believe this has benefits for both the coherence of this document and its potential appeal to an audience of both design researchers and practitioners. On this last point, the combination of practice and theory developed throughout writing the thesis has been usefully employed in papers I have recently written (see Luscombe 2017 and Luscombe 2018). I have found this an efficient means of making what might be abstract ideas tangible (a point I claim as one of the contributions of this thesis, see 1.4, point 7).

Despite these benefits, there are some disadvantages to the unconventional thesis structure, which are worth noting and reflecting upon. The first is that it makes navigating the document more challenging than it might otherwise have been. A more familiar structure would perhaps provide quicker access to the essential components of a PhD thesis, and be easier to read out of sequence. I have tried to mitigate this loss by including a list of my contributions and where to find them throughout the thesis in the introduction (see 1.4). And I have attempted to thoroughly cross-reference the document with links to relevant sections, enabling precursory ideas to be easily found if it is read non-sequentially.

Another potential disadvantage to the chosen structure is that it makes the aims, objectives and findings of the research more difficult to track. It is for this reason that I have written a chapter on the methods and *chronology* of the research. Here I detail the relationship between the objectives and research questions throughout (see 2.5), in order to make clear how they were developed over time.

One further potential criticism of the structure of this thesis might be that it does not appear to provide raw data, made available for subsequent (re)interpretation by another researcher. In Chapter 2, I justify the presentation of "cooked" data according to my subscription to a constructivist approach (see 2.4.2). But I would also argue that, by building my contributions with careful reference to existing literature, and discussing only well-documented, widely-used techniques (see 2.6.6 and 2.6.8), there is nothing to stop others drawing on the studies of Chapters 4, 5 and 6 in order to refute, support or extend my contributions. I have also provided an Appendix, including photographs of the workshop environments used for the studies, a selection of photographs used as the basis for the line drawings throughout the thesis, and a selection of scanned pages from my notebooks.

1.4. Summary of Contributions

Below is a summary of the contributions I claim to have made, along with details of where they may be found in the thesis, and where they have been published elsewhere. They are listed in the order they are presented throughout this thesis.

1. I present an argument that recasts the making process as a means of thinking, rather than merely transcribing antecedent ideas. I draw on literature from disciplines where this argument has been well-rehearsed, and contribute a novel synthesis of existing ideas in terms relevant to design studies and practice. (Chapters 2, 3 and 4) (Also published in Luscombe 2017 and Luscombe 2018)

2. I present an analysis of techniques that describes their simultaneously *epistemic* and *pragmatic* nature; I argue that techniques are a means by which to find out about the world and change it simultaneously. (Chapter 4) (Also published in Luscombe 2017 and Luscombe 2018)

3. I present a novel critique of the work of David Pye, according to the theoretical foundation developed in contributions 1 and 2. (Chapters 4 and 7) (Also published in Luscombe 2017)

4. I introduce the term ‘epistemic character’ in order to frame a new subject of interest—how techniques structure design processes. I argue that we may investigate the epistemic character of techniques, and I provide examples of how such investigations may be pursued. (Chapters 5 and 6) (Also published in Luscombe 2018)

5. I introduce three questions that may be asked of a technique’s epistemic character: What are the *questions posed* by a technique?; What is its *step-character*?; and what is the *nature of the emergent result*? (Chapter 5)

6. I provide a discussion of how the features of epistemic character influence the distribution of decision making throughout design processes. This offers a novel

insight into historic dichotomies of hand and machine tools, as I suggest there is a more fundamental distinction to be made, between *processes throughout which things emerge step-by-step*, and *processes in which things are planned in advance of their execution*. (Chapters 6 and 7)

7. Through a distinctive, designerly subject of interest (the detailed study of design and making techniques), I develop a means of communicating and promoting extra-disciplinary theoretical ideas in a way that is relevant for design practice.

1.5. The Researcher

The topic of this research is a consequence of my interests as a design practitioner, a teacher of design and an amateur woodworker. My practice is mostly concerned with the design of furniture, usually made from wood. I teach onto a Three-Dimensional Design undergraduate degree, which sees students design and make both furniture and products. And I consider myself an amateur woodworker—I make prototype and finished pieces of furniture, and a range of things in my home workshop for fun.

Each of these interests, along with my more recent membership to the world of design research, has combined to inspire the direction and outcomes of this research. As I make clear when outlining my epistemological commitments (see 2.4), this is a study where the findings and myself are interactively linked. It should help, therefore, to briefly describe the influence that I feel my experience as design practitioner, teacher and amateur woodworker has had upon the research. In Chapter 2 (see 2.5), I also discuss my development as a design researcher, alongside a description of this study's chronology.

Design Practitioner

I have a degree in furniture and product design, professional experience in design practice, and have continued to design and make things throughout the course of my PhD. An engagement with the practice of design (both through my own work and through relationships with other practitioners) has doubtless had a significant influence on my research. Of most benefit has been the ability to interpret extra-disciplinary literature from this perspective. Being aware of how ideas might be applied in the context of designing and making has steered my interests through unfamiliar texts. Although I have enjoyed diversions into apparently irrelevant subjects and unrelated ideas, I hope that anchoring the project in my knowledge of design practice has helped to stop these leading me too far astray. The acid test of trying to correlate theory with my experience has been invaluable. And I hope this will ensure the ideas I present in this thesis are accessible to others.

It should be noted however, that my tolerance for literature that would, at one time, have appeared hopelessly obscure has certainly expanded. As I describe in the next chapter, these new ideas have had a revelatory effect on my thinking. For the purposes of the research, this has opened up new lines of inquiry, allowing me to interrogate practice from a new perspective. And, from a personal perspective, it is the aspect of the PhD that I have enjoyed the most.

On a practical level, already being familiar with the context of workshop practice, and techniques typical to designing and making practice has also enabled me to target my first-hand studies effectively.

Design Teacher

Teaching design at degree level has given me full-time access to "workshop practice". The Three-Dimensional Design degree I help to teach is centred around designing through making. Our students draw and make prototypes to develop designs for furniture and products. The longer projects then see them create fully-resolved final prototypes or products, in "real" materials.

The workshop environment has enabled me to engage in 'persistent observation' (Guba 1981, p.85), by allowing me the time and experience to develop, test, and modify my ideas. Potential themes of interest have come and gone throughout this extended interaction with my subject of study, leaving only the 'pervasive qualities' (ibid.) I present here.

It has also been helpful to trial some of the ideas of this thesis as they emerged, by incorporating them into my teaching practice. Attempting to make the concepts relevant and interesting to students has been a useful challenge, and it has informed the thesis' concurrent discussions of "theory" and "practice".

Amateur Woodworker

Whilst also a large component of my design practice, woodwork (particularly hand tool woodworking) is a personal hobby. I have been able to draw on my knowledge of this subject in order to find useful ways of investigating and describing epistemic character. Keeping up-to-date with the online community of woodworking blogs—an arena in which discussions of technique are fundamental—has also been a pleasurable and informative aside to my research.

1.6. The Context of Workshop Practice

The "workshop practice' of my title is perhaps best described by flicking through this thesis and looking at the illustrations, or looking to the photographs in the Appendix. To be clear about the features of the specific workshop that has been the setting for this research, however, I list them below:

Metalworking forge; welding equipment; fine metalworking tools and benches; tube bending and notching machines; woodworking machines; woodworking hand tools and benches; machine tools (lathes and milling machines); CNC machine tools; CNC routers; laser cutters; 3D printers

This is the collection of equipment I have had access to at Northumbria University. In my design practice, throughout the course of the PhD, and through my teaching, I have used all of the above equipment. Despite this range of experience, however, this thesis draws on a more limited set of techniques in order to explore the idea of epistemic character (see 2.6.6). This is because I have not aspired to develop a comprehensive account of the epistemic character of any and all designing and making techniques. In this thesis, I have been interested in trying to define what I mean by the term, and developing effective ways of communicate the idea (see Chapter 5).

1.7. Prior Publication

Alongside more informal presentations of my research throughout my PhD, I have presented work at the *All Makers Now?* conference (June 2014, Falmouth) and *Research Through Design 2017* (March 2017, Edinburgh). These have been valuable opportunities to test and develop my ideas.

I have also had a paper accepted by *Design Issues* (Luscombe 2018). The paper could be considered an abridged version of this thesis. It suggests that we might apply the theory of extended mind (see 3.2.2) in order to better understand the potential ways in which techniques can structure and support design work. It makes this argument through a comparison of rulers and dividers as tools of measurement (see 5.1), and introduces the term "epistemic character" in the conclusion.

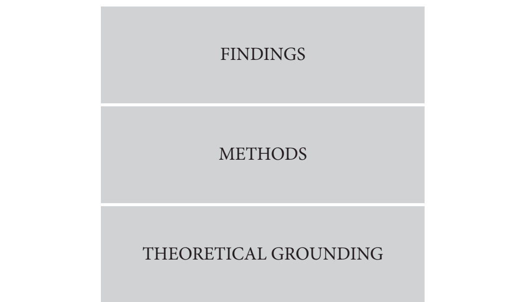
I attach this paper, along with the one presented at *Research Through Design 2017*, because they are composed of sections of this thesis, and represent occasions where the arguments made herein have been subject to peer review (see Accompanying Materials).

2. Methods and Chronology

Throughout this research, there has been a co-development of questions and methodology that now feels difficult to untangle. The reason for this entanglement can be summarised as follows; it was only through discovering appropriate methods of analysis (and their associated theoretical foundation) that some of the research questions became valid. My questions and methodology have thus become inextricably linked. In this chapter then, I aim not just to describe the theoretical underpinnings and methods I have used, but also give an account of this co-evolution.

Take, for example, a question that has come to drive the research: “How do the techniques of making designs structure and support design practice?”. This is a question that presumes the techniques have any influence at all, and that the nature of this influence can be a subject of study. Whilst common sense accounts[1] might seem to qualify the first of these presumptions, it took some time to develop a more substantial theoretical grounding from which to approach the issue. I have come to discover that a question like this requires a particular understanding of the relationship between thought and action, thus enabling methods of analysis that would be otherwise redundant, to provide answers that themselves depend on the same understanding of the relationship between thought and action. When drawn as a stack of blocks, like in Figure 2.1, the “foundational” quality of the theoretical grounding becomes apparent. If it was removed, the methods and findings would fall down.

Figure 2. 1 The relationship of my theoretical grounding, methods and findings



[1] Architectural theorist Branko Kolarevic, for example, observes the respectively rectilinear or blobby buildings designed by architects drawing by hand, or using computer software (Kolarevic 2003) (see also Mitchell 2001; Robertson and Radcliffe 2009).

Owing to the situation illustrated in Figure 2.1, developing and explicating the theoretical grounding for the research has become more vital than I ever expected. This is now one of my main contributions, and a crucial component of my argument as a whole. The methodology has become ‘simultaneously prerequisite and product, the tool and the result of the study’ (Vygotsky 1978, p.65). At the beginning of this PhD, however, I had no intention of addressing intractable issues such as “what is the difference between designing and making?” (see Chapter 3), or seemingly obscure ones like “where does the mind end and the world begin?” (see 3.2.2). And I would have been highly sceptical about the value in doing so. These developments in my thinking are discussed in more detail in a discussion of chronology below, but I begin by summarising them here, to introduce the chapter’s themes and sections.

2.1. Summary of the Study’s Development

At the beginning of my PhD programme, I became deeply impressed by the writing of the furniture designer, woodworker, naval architect and Royal College of Art professor David Pye. Having engaged in a study of designing and making, it was in some ways disheartening to see that he had written so brilliantly on the subjects over forty years ago. His two most famous books, *The Nature and Art of Workmanship* (1968) and *The Nature and Aesthetics of Design* (1978), seemed to me to have said it all. Pye expertly dismantles ‘the doctrine that form follows function’ (1978, p.12). He dismisses the imprecision of the word *skill*, because ‘you can make it mean what you want it to mean’ (1968, p.52). And, perhaps most famously, Pye’s definition of the ‘workmanship of risk’ and the ‘workmanship of certainty’ (see 4.1) brought a new clarity to the subject of ‘craftsmanship’ (another word Pye didn’t like). What’s more, I kept finding contemporary scholars across disciplines who were similarly appreciative. Anthropologist Tim Ingold draws on Pye’s dissection of workmanship (see, for example, Ingold 2011, p.59) and his discussion of “truth to materials” (see, for example, Ingold 2011, p.29), to build intricate arguments on a variety of subjects. Contemporary craftspeople like Peter Galbert (2015) and Robin Wood (2011) find resonances between Pye’s writing and their work. In design literature, Pye’s work has a lasting legacy (e.g. Jones & Jacobs 1998; Chamberlain & Roddis 2003). And craft theorist Glenn Adamson goes so far as to describe Pye’s book on workmanship as offering ‘the most compelling technical discussion of skilled work ever written’ (2007, p.72). At every turn, I was reminded of the exceptional contribution of David Pye, and was left struggling to see what more could be said.

In particular, it was Pye’s thinking on the relationship between designing and making that was difficult to see beyond. This is perhaps most clearly expressed when Pye declares that the aim of 'good workmanship' is to realise an antecedent design (1968, p.30). In this definition, and throughout the rest of Pye's writing, the underlying sequence of events is clear—first comes the design, and then follows its material realisation (I critique this aspect of Pye's work in detail in Chapter 4). This one-way relationship between designing and making led my questions to a dead end. Under such a model, how could the techniques of material engagement influence design practice? If "ideas" always come first, how can they be influenced by the techniques of their realisation?

My progress beyond this impasse was gradual, as I slowly built familiarity with a body of literature that challenges this one-way relationship between designing and making or, more generally, between cognition and action. I discovered alternative positions that did not assume cognition to precede action (see 3.2). I read accounts that claimed some actions were more like "thinking" than "doing" (see 4.2). And I even learned of theories that suggested the "mind" could be understood to include features of the external environment (see 3.2.2). I thus became involved in an interdisciplinary literature review that has illuminated and sustained my PhD ever since. This reading had a revelatory effect. I had found a basis from which tools and their associated techniques could be analysed as more than just a means to a pre-specified end. I felt reassured that making techniques could be considered as ways of working things out—as ways of thinking.

Reading around this subject thus changed my dead end into a fork in the road. One path led to a cul-de-sac, where commonplace assumptions about the relationship between designing and making (see 3.1) would have inhibited the questions, methods and findings of this research. The other path led me through the fields of anthropology, archaeology, cognitive science and philosophy of mind. Along the way, I have come across a web of links between scholars from these disciplines and beyond. United in their criticism of dualist interpretations of mind and matter (see 3.2 and 3.3), each one provides their own particular contribution to an emergent model of how better to understand the relationship between humans and the world of materials.

2.2. Chapter Summary

This journey has formed the first of my two methods—an interdisciplinary literature review centred on the relationship between designing and making. I discuss this method in the following section (2.3), where I justify my adoption of an interdisciplinary approach, consider the potential difficulties with such an exercise, and describe how I hope to have maintained academic rigour. Wary of having already introduced some "big ideas" (i.e. that cognition does not necessarily precede action, or that our "minds" might not be located in our heads), here I expand a little on the content of the literature review, to help outline the relevance of these issues. To avoid creating an overlong preview of subsequent chapters, however, I do this by documenting a similarly intentioned interdisciplinary exercise from archaeology (Knappett 2005). This allows me to introduce the reasoning behind my interdisplinarity, without detailing too much of the argument made in Chapters 3 and 4.

As introduced above, having reflected on my research, I am unable to unravel an account of my methods from their subsequent findings. Under a positivist framework (Guba & Lincoln 1994) they would doubtless be easier to isolate. The entangled nature of my research, however, is more typical of its constructivist basis. My consideration of this research paradigm forms the next section of this chapter (2.4). Here I consider several aspects of the paradigm's influence on my work: its commitment to what constitutes "knowledge"; how it has informed my relationship with the subject; the tone of voice it has lead me to adopt throughout this thesis; and how my work might be judged according to its associated criteria of quality.

I then return to the chronology summarised above (2.5). In a nod to a popular conception of design expertise, I borrow the metaphor of the "T-shaped designer" (Brown 2009) to help describe how both this study, and my knowledge, has developed over time. A series of T-shaped illustrations show how a broadening of my theoretical horizons (the horizontal of the "T") throughout the research has allowed me to delve deeper into my subject specific knowledge (the vertical of the "T") and, ultimately, make a contribution to this field. The illustrations are also intended also to provide more clarity on the entangled nature of my questions and methods, and the relationship between my literature review and my second research method—a first-hand study of techniques.

I then go on to describe these first-hand studies (2.6). I discuss; how the theoretical grounding developed throughout my literature review has allowed me analyse the influence of techniques; the definition of *technology* as the study of techniques; existing approaches to the study of techniques; how I documented the process; the back and forth of reading and doing; the role of "how-to" literature; and how I developed the theme of epistemic character.

2.3. Research Method 1: An Interdisciplinary Review of Literature

By citing a review of secondary sources as one of my research methods, I am adopting an approach common to discursive PhD theses from the humanities (see Knott 2011, for a thematically relevant example). In disciplines where the (re)interpretation of existing texts and artefacts is the dominant form of scholarship, it would be possible to pursue a PhD (or even a life's work) using only this method. For the purposes of this research, the inspiration of an on-going literature review has allowed me to develop insights on practice that I would never have conceived independently. It is by drawing together ideas from a range of disciplines that I have developed a new means of interrogating the techniques of designing and making.

The reading and writing that forms this interdisciplinary literature review has been distributed throughout the course of the PhD, rather than completed (as might be more typical) within the early stages. This has given me the time to explore a much broader range of literature than I otherwise would have, and allowed me to follow my developing understanding of the research questions, towards relevant disciplines and ideas (see 2.5). Because of this developing understanding, at no point did the literature review employ any fixed and well-defined criteria for inclusion. As I describe in 2.3.3 and 2.5, the process of selecting texts was guided by following links between different scholars, and identifying and investigating shared points of reference. Reading, writing, and studying practice along the way has allowed me to identify relationships between ideas from the literature and my experience of techniques (see 2.6). This approach has also informed the structure of this thesis (see 1.3), which distributes key ideas from other scholars alongside discussions of technique. Rather than using a dedicated literature review chapter to identify a "gap" in existing knowledge (which could then be addressed as a contribution to knowledge), this thesis therefore describes the relationship between existing ideas and my new contributions throughout[2].

A key contribution of my research is in the way in which it frames a new subject of interest—how techniques structure design processes. It is in the framing of this subject, and developing an appropriate theoretical grounding for its study, that the integration of extra-disciplinary ideas has been most useful. This aspect of the research was in part inspired by the work of archaeologist Carl Knappett, whose similarly interdisciplinary study, *Thinking Through Material Culture: An Interdisciplinary Perspective* explores how other fields have tackled issues he claims to have been neglected by his own (2005). I introduce Knappett's work to my discussion of method for two reasons. Firstly, the theme of his criticism, whilst directed towards his own discipline, closely resembles the argument I develop in Chapters 3 and 4. In short, Knappett portrays the default archaeological position to be founded upon a scheme that draws too crude a line between action and cognition. In Chapters 3 and 4, I

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[2] One such example is in Chapter 6, where I extend anthropologist Tim Ingold's concepts of wayfaring and transport, alongside a discussion of distributed decision making (see 6.3).

develop a similar position with respect to commonplace assumptions on the relationship between designing and making. This semblance with the themes of my work is what drew me to Knappett's work in the first instance, and what convinced me that a similarly interdisciplinary approach would be helpful for this research. My second interest in *Thinking Through Material Culture* is a methodological one. I am interested in the way in which Knappett builds his thesis through an assemblage of literature from different disciplines. For the present discussion of methodology, it is this aspect of the work that I will be focusing on. Before doing so, however, it will be helpful to introduce the basics of Knappett's argument, to help explain the necessity for his (and, ultimately, my) interdisciplinary scope. This exercise will hopefully also begin to illuminate what a "scheme that draws too crude a line between action and cognition" looks like.

2.3.1. Knappett's Criticism of Archaeology

Whilst archaeology, Knappett argues, has developed increasingly sophisticated methods for the analysis of artefacts themselves, he finds it to have failed to construct 'similarly sophisticated theoretical models' for understanding how those artefacts have been made and used (ibid., p.1). Knappett criticizes the default archaeological approach to material culture, and offers an alternative synthesized from extra-disciplinary sources.

Central to Knappett's criticism is his challenge to the 'default archaeological approach' (ibid. p.3). This approach is epitomized, according to Knappett, in a quote from V. Gordon Childe's classic archaeological text, *Piecing Together The Past*;

> 'The archaeological record is constituted of the fossilized results of human behaviour, and it is the archaeologist's business to reconstitute that behaviour as far as he can and so to recapture the thoughts that behaviour expressed.' (1956, quoted in Knappett, ibid., p.3)

For Knappett, this short passage illustrates two underlying assumptions that dominate archaeology. The first of these is a 'clear hierarchy [in which] thought is primary, behaviour is secondary, and material expression is at the bottom of the chain' (ibid., p.3). In Childe's passage, we find the idea that material remains can be studied in order to trace back towards an antecedent idea in the mind of their creator (via what Hawkes has called the 'ladder of inference' 1954, quoted in Knappett, ibid., p.4[3]). When applied to the analysis of fragments from the past, this model presumes a chain of events that starts with an idea in a mind and ends with a thing in the world. The second assumption described by Knappett thus follows;

[3] See also, Malafouris 2013, p.31.

behavior, in this model, is merely a means of realising pre-exiting thoughts in the material world. '[G]iven that thoughts are separated from objects by behavior,' Knappett writes, 'it follows that the internal mind is buffered from the external world via the medium of action.' (ibid., p.3)

It is this fundamental distinction, between an 'internal mind' and the 'external world' that Knappett challenges. I return to the content of this criticism, which is shared by many other scholars across disciplines (e.g. Farnell 1999; Burkitt 1998; Ingold 2013a), in more detail throughout this thesis. To summarise its significance to Knappett's interests; separating out 'mind' and 'matter' according to what he calls the 'Cartesian dualism' (ibid., p.3) precludes any investigation of how the latter may be entwined with the former. It is a position that neglects the potential for action, or any non-human actant, to have any influence on creative processes. The model thus has a profound effect on the nature of questions that can be asked of an archaeologist's source material, and leaves them, according to Knappett, 'aspiring to mentalism, but forever condemned to materialism' (ibid., p.168).

Having detailed the flaws in this approach, *Thinking Through Material Culture* goes on to promote a model of archaeology wherein artefacts should be understood not only as the end results of human thoughts and behaviour, but as themselves active participants, influencing and directing cognition as they are both made and used. This is a position that takes cognition to be distributed across both human and non-human "agents" (see 3.2 and 5.3).

2.3.2. The Value of Interdisciplinarity

In his exercise to rethink the theoretical foundations of archaeology, Knappett sets himself an ambitious task—attempting to both reveal the assumptions of his discipline, demonstrate their flaws, and provide a valuable alternative. It is this ambition that necessitates his interdisciplinary scope. Because the default approach is so ingrained in archaeological thinking and writing, Knappett must look beyond the boundaries of his own field, synthesizing an argument from across disciplines. The spectrum of literature used is broad, presumably because, as Knappett notes, the default position he identifies pervades not just archaeology, but much of the social sciences[4]. Throughout the book then, Knappett borrows from 'cognitive science, psychology, sociology, anthropology, and history' (p.1) in an effort to piece together a more effective theoretical grounding from which to understand the

[4] This is in accord with Tim Ingold, who observes, '[T]ime and again, scholars have written as though to have a design for a thing, you already have the thing itself' (2013a, p.22). See 3.1.

relationship between mind and matter. Through careful scholarship, non-native ideas from these fields inspire and lend credibility to Knappett's thesis[5].

Throughout my research, I too have drawn on a range of sources from across disciplines. For Knappett, interdisciplinarity is necessary in order to address a fundamental issue that affects the methods of analysis his discipline might adopt, and the kinds of questions it can ask. It plays the same role in my research. I have looked beyond the bounds of writing directly associated with the fields of design and craft practice, in order to interrogate the same fundamental subject. The issue I'm interested in is how we can better understand the influence of material engagement upon design processes.

In assuming that material engagement has any influence at all, however, I am already taking a position on the relationship of cognition and action that is not well represented in design studies. And, like Knappett, before studying the subject itself in any detail, it is first necessary to challenge the default approach to tool use and design. In short, this requires me to question what has been called the 'intramental' (Gedenryd 1998, p.57) approach to design activity and tool use, wherein techniques are not credited with any influence on the outcomes of practice.

Throughout the thesis, I make the case for an appreciation of the ways in which techniques are not inert means by which to transcribe ideas from our heads into the world, but active participants in the creative process, which themselves have a significant influence on the process. This is in contrast to what could be called the traditional cognitivist understanding of design activity, which, as I argue in Chapter 3, locates all thinking inside the heads of practitioners. Thankfully, the essence of this argument has been well rehearsed across other disciplines, providing me with a rich source of material from which to build my case. Indeed, whilst the ideas drawn from other disciplines within this thesis might appear quite novel in design studies (and took me some time to become familiar with), elsewhere they are increasingly well-recognised theoretical positions (see Marsh 2010). Models of distributed cognition[6] have been proposed, challenged, and proven methodologically effective. Being able to draw from these disciplines has proven the value of my interdisciplinary scope.

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[5] Whilst the tone of Knappett's book is mildly revolutionary, it should also be noted that, in the field of archaeology, he is not alone in his exploration of new ways of dealing with material culture (see, for example, Renfrew 2010).

[6] In addition to *distributed* cognition, the terms *situated*, *extended*, *embodied*, *enactive*, or *dynamic* cognition are also in use. As cognitive scientist Leslie Marsh points out, these are not precisely defined terms (2010). I stick to *extended* and *distributed* cognition throughout this thesis, because they are the phrases used by those I cite.

In summary, I have used an interdisciplinary approach to lay a credible theoretical foundation for my study of techniques, and also to inspire the analysis of techniques.

2.3.3. Taking Care with Unfamiliar Sources

In light of these benefits, I believe the interdisciplinary approach presented here to be a necessary requirement of this study. Very little of the subsequent study or analysis of tools and techniques would have been possible without first laying this theoretical foundation—the credibility of which rests on a careful synthesis of extra-disciplinary ideas. But, although similar projects in comparative literature review are not uncommon (see Ingold 2013a; Bennett 2009; Malafouris 2013; Sennett 2008; and Pickering 1995, for a selection that have inspired this thesis), they are also not without their risks. In the introduction to *Thinking Through Material Culture*, Knappett points out that '[t]here are inevitable dangers in working with relatively unfamiliar areas such as cognitive science' (p.2). Perhaps the most serious of these dangers is the risk of misappropriation, where decontextualized sources are reassembled into a narrative that disregards the authors original intent or, perhaps more likely, extrapolates too far from their original claim. Another risk to which Knappett alludes in his preface is that of heading 'off along blind alleys' (p.vii), presumably by following links through unfamiliar literature, until you catch yourself spending hours reading something that is almost certainly irrelevant to the research in hand. Of these two pitfalls, I am certainly guilty of the latter. But I have done all I can to avoid the first, chiefly by finding my sources through work like that of Knappett, where they have already been appropriated in support of the claims I am making. In doing so, I am safe in the knowledge that the appropriation has been both carefully considered by these "secondary" authors, and typically peer reviewed before being published in their field.

I have, therefore, not aimed to unearth previously neglected literature in support of my theoretical foundation. Whilst I might have enjoyed exploring blind alleys until I happened upon a paper previously unappropriated by scholars of distributed cognition, such an effort would have been prohibitively time consuming. My claim for the originality of the theoretical foundation and methodology of this study does not lie in the use of entirely novel sources, but in pulling together those already used by others, as part of a coherent argument that is newly relevant to the study of tools, techniques and design practice. To give an example, in Chapter 4, I draw on a study of Tetris gameplay, in which cognitive scientists David Kirsh and Paul Maglio introduce the concept of 'epistemic action'—a category of actions that are used not to achieve results in the world, but to support cognition (1994). This is a key theme throughout this thesis. I did not, however, happen upon Kirsh and Maglio's paper in its original context (the journal *Cognitive Science*). I discovered the work having seen it discussed by a variety of other authors, all using the study as an example of how thinking can be supported by action in the world (see, for example, Gedenryd 1998; Clark 1997; and Malafouris 2013, who all cite Kirsh and Maglio's study). Following citations back to the original paper, I developed an understanding both of the original method, intent and findings of the study, and an idea of how it might be weaved into an argument for distributed models of cognition. Kirsh and Maglio's paper is remarkable in the number of times it has been employed by others in support of such models, but this story, of discovering 'source' literature through its citation in other work, is typical of most references I use throughout this thesis.

Knappett describes how his interdisciplinary approach attempts to 'create a new "network" in which previously separate entities and ideas are interwoven' (p.2). I have shared this aspiration, but would add that, in addition to creating my own such network of interconnected ideas, examples like Kirsh and Maglio's paper (as a commonly referenced touch-point for those writing about distributed cognition or extended mind) reveal the threads of connections already present in this cross-disciplinary field of inquiry. I feel as though I have been discovering an existing network of ideas, as much as weaving a new one. My theoretical foundation might be unique in its emphasis of certain sources and ideas over others, according to the particular interests of my study. But I feel assured, by the credibility of this existing field, that my position is an academically rigorous one.

2.3.4. The Interdisciplinarity of Design Literature

The adoption of extra-disciplinary theory is not new to design studies. Indeed, some of the most ubiquitous ideas have been borrowed from elsewhere. These include, for example, the notion of *affordances*, as developed by ecological psychologist James Gibson (1979) and popularized in the design literature by Donald Norman (1998); Donald Schon's concept of *framing* problems (1983), as cited in, for example, Kees Dorst and Nigel Cross's work on creativity in design processes (Dorst and Cross 2001); descriptions of design-driven innovation, developed in management studies (Verganti 2009; Norman and Verganti 2014); and, in the early days of the Design Methods movement, Christopher Alexander's adoption of mathematics (1964). This is in sympathy with the popular notion of designers making connections between different interest groups, or, as designer Tim Brown puts it, being "T-shaped" (2009), with a deep knowledge of their particular field (the vertical of the "T") and a working knowledge of a wide range of complementary disciplines (the horizontal of the "T"). Design theory has long since looked beyond its own boundaries for ideas. In fact, even the 'T-Shape' metaphor was itself borrowed from management consultancy.

2.4. A Constructivist Research Paradigm

The research paradigm upon which this inquiry is built can be defined as constructivist. On this basis, I have not sought to discover and define absolute, objective 'truths'—I instead subscribe to the belief that '[t]ruth is a matter of the best-informed and most sophisticated construction on which there is consensus at a given time' (Schwandt 1994, p.128). By making my methodology and theoretical foundations clear, and attempting to present all my arguments through careful scholarship, I hope to have created a well-informed and sophisticated construction that might answer this requirement. I take much of my understanding of the constructivist research paradigm from methodologists Egon Guba and Yvonna Lincoln.

2.4.1. The link between an investigator and their research

I also assume, according to the constructivist paradigm, that myself (the investigator) and the object of the investigation are 'interactively linked so that the "findings" are *literally created* as the investigation proceeds' (Guba and Lincoln 1994, p.111, emphasis in original). For the purposes of clarity, I have tried to give an insight into this creative process through my discussion of the study's chronology (see below, 2.5). And, whilst I know this to be a difficult ambition to achieve, I have attempted to write this thesis in such a way that my 'findings' might reveal themselves to a reader, and so be re-constructed, in a similar manner. Despite having already made clear my 'contributions' then, I would hope that the remaining words do not serve only to provide 'evidence' for these claims, but allow a reader to experience the same kind of active, investigative journey that I have undertaken. My reasoning for this is consistent with a constructivist understanding of knowledge accumulation—I hope that an active experience would suggest to a reader other (complementary) findings that I have not yet considered, inspiring 'ever more informed and sophisticated constructions' of their own (ibid., p.114).

2.4.2. Working with 'data'

Although I have been less explicit about the totality of my 'data' than I might have been if working in an alternative paradigm, I believe my treatment of this subject is typical of other constructivist projects. The the two kinds of 'data' I have been working with are multidisciplinary literature, and my first-hand experience of designing and making techniques. A thematically relevant example of a constructivist approach to the former can be found in architect Lars Spuybroek's *The Sympathy of Things* (2011). And a thematically relevant constructivist approach to the latter can be found in anthropologist Tim Ingold's reflections on sawing a plank of wood (2011, p.51). Having accepted the irreducible relationship between the investigator and the findings, neither of these examples, as is typical of constructivist projects, make available significant amounts of “raw data”—it is served only (to extend a metaphor) once it has been “cooked” into an argument. In my case, even if I were to list every piece of writing read throughout the study (in addition to the ones cited throughout this thesis), and painstakingly document every single occasion when I have employed a designing or making technique, I could still not claim a different investigator would reach the same conclusions from this data. This is not to suggest there is any mystery surrounding my sources—all cited literature has been clearly referenced and I have been careful (as described in 2.6.8) to demonstrate my practical work is consistent with widely-reported techniques of competent tool use. It must be acknowledged, however, that as soon as I, or anyone else, begins working these sources in a constructivist paradigm, they are no longer “raw” in an objectivist sense, but immediately orchestrated by the inquirer, according to their interpretations and the emergent findings of the research.

2.4.3. Tone of Voice

The tone of this thesis is also a result of its constructivist basis. ‘The inquirer’s voice’, as explained by Guba and Lincoln, ‘is that of the "passionate participant" actively engaged in facilitating the "multi voice" reconstruction of his […] own construction as well as those of all other participants’ (1994, p.115). This is a theme colourfully explored in Lars Spuyborek’s introduction to *The Sympathy of Things*. In his aim of revitalising John Ruskin’s Gothic ontology, Spuybroek aims to project Ruskin forwarded through time, so that he meets other ‘participants’ with whom he might share ‘theoretical affinities’ (2011, p.7). Using the metaphor of space travel, wherein probes circle planets, using gravitational fields to accelerate, Spuybroek lets Ruskin ‘encounter William James, revolve around him, and absorb some of his thought, but not enough to slow him down; sweep around Henri Bergson, acquiring more speed; and again around a few Germans (Theodor Lipps, Vilhelm Worringer and even Martin Heidegger); eject him over the twentieth century […], with its world wars, its minimalism and its deconstructivism; and stop him so that he appears suddenly in our own age, like Doctor Who, meeting the likes of Bruno Latour and Peter Sloterdijk’ (2011, p.8). I have at times conceived of my research (in much more mundane terms) as an opportunity to gather guests for a fictional dinner party, with my text being an imagined version of their conversations. This has informed the character of my writing, which can be usefully contrasted with that of an alternative paradigm—critical theory. As described by Guba and Lincoln, an important difference between constructivism and the similar paradigm of critical theory, is the tone of voice adopted by the investigator: where a critical theorist would adopt the more authoritative position of a ‘transformative intellectual’, as is necessitated by their advocacy of lesser-heard voices (1994, p.113), the constructivist is a facilitator of dialog between alternative positions. The final aim is ‘to distill a consensus construction that is more informed and sophisticated than any of the predecessor constructions (including, of course, the etic construction of the investigator)’ (ibid., p.111). I have thus attempted to keep my dinner party guests in convivial spirits, and used their ideas to form a ‘dialectical interchange’ (ibid., p.111). My interdisciplinary use of literature here proves highly valuable—as Guba and Lincoln describe, knowledge is most likely to advance in this way ‘when relatively different constructions are brought into juxtaposition.’ (ibid., p.113)

2.4.4. Evaluating Constructivist Research

The last point to make regarding my adoption of the constructivist paradigm is on the notion of quality. If we are to acknowledge the coexistence of ‘multiple knowledges’, each one subject to continuous revision (ibid., p.113), how can we be assured of the ‘goodness’ of an inquiry (ibid., p.114)? According to my constructivist commitment, I suppose the job of determining the goodness of this inquiry is one for others, as they place it in the context of similar constructions. I would suggest, however, that a reader could use the following questions (as I have throughout the study) to help guide their determination of quality. These are a selection of the criteria suggested for the evaluation of constructivist research by Guba and Lincoln (see also, Guba 1981, for those relating to trustworthiness).

<u>Criteria of Trustworthiness</u>

On the criterion of *credibility*: Are my arguments internally valid—do they make sense? Have I demonstrated that my constructions are built out of other credible constructions in a rigorous manner? Have I been engaged in the subject for a sufficient amount of time? Is the argument of this thesis coherent? Is my account of the study’s chronology consistent with its findings? Have I successfully triangulated concepts from multiple sources? Have I tested the ideas via peer review?

On the criterion of *transferability*: Are my arguments externally valid—are they good enough to be of use to others? Are the ‘thick descriptions’ (Geertz 1973) I provide in my synthesis of arguments from other literature, and in the documentation of designing and making techniques, suitable for application elsewhere?

On the criterion of *confirmability*: Is my data reliable? Are the literary sources I cite trustworthy? Are my descriptions of designing and making techniques competent enough to support the analyses I have made? Do my two research methods suitably overlap in pursuit of my objectives? Have I made clear the relationship between my theoretical foundation and my findings?

Criteria of Authenticity

On the criterion of *educative authenticity*: Does my work lead to an improved understanding of the constructions of others? Would the findings be helpful to a design researcher and/or design practitioner? Does this thesis help to understand it's subject from a new perspective?

On the criterion of *catalytic authenticity*: Could my work serve to stimulate further research? Does it point towards further constructions? If I have promoted a new perspective from which to understand my subject, is it a valuable one which might be applied elsewhere?

2.5. A T-shaped Chronology

Although I remain unconvinced that design professionals are especially T-shaped (over and above people in other jobs)[7], I nonetheless find Tim Brown's "T" (2009) (see 2.3.4) to be a useful metaphor. I now use the "T" to illustrate the development of my two research methods and the chronology of my research. In addition, I describe the objectives and research questions driving the research at various times, to summarise their development.

The first of my methods (the synthesis of interdisciplinary literature introduced above), can be understood as a method of extension along the horizontal of the "T"—an extension out into previously unexamined (both by myself, and design literature more generally[8]), but complementary fields. This extension has helped to lay a credible theoretical foundation for the second research method—a first-hand exploration of the epistemic character of techniques, which has extended down into vertical of the "T". This "vertical" method, described in detail in the next section (2.6), aims to contribute to knowledge within the field of design theory, by offering a novel means of understanding the influence of techniques on design practice. Whilst the study has been primarily motivated by this second objective, in retrospect I believe the synthesis of literature developed in support of this task can itself can be considered a valuable contribution. As I have suggested elsewhere (Luscombe 2018), models of distributed cognition provide a foundation from which other studies could interrogate the influence of techniques on design and making practice. I believe the

[7] See McCullagh (2010) for a discussion of this subject.
[8] I discuss exceptions to this tendency in 3.2.1.

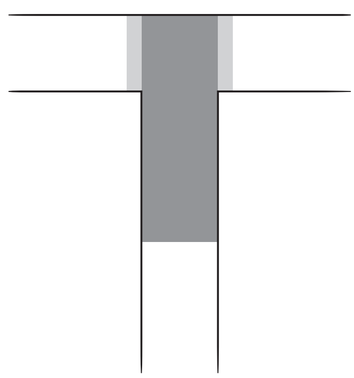
methodological approach supported by this wider “T” could, therefore, be applied more generally.

In addition to clarifying the relationship between my two methods and their respective contributions, I also find a repurposing of the metaphorical T-shape to be useful when plotting the PhD research against my own education as a researcher. This is perhaps best explained by returning to the issue at the start of this chapter—the chronology of the development of my research methods and my evolving understanding of the study. In Figures 5.2, 5.3, 5.4, 5.5 and 5.6, I use the T-shape to illustrate this chronology.

2.5.1. Part One

Imagine I began as illustrated in Figure 2.2. At this stage, I had first-hand knowledge of the practice of designing and making, and was acquainted with disciplinary-specific theory, such as that of David Pye’s. Both my knowledge and my understanding of my research, however, were roughly ‘I’ shaped. I knew that I wanted to contribute to the base of this “I”—from my practice as a designer (and from teaching the subject) I knew that there was something more to be said about the influence of techniques on the process of working things out—but I didn’t know what form such a contribution could take. This is the frustrating position I described in the opening paragraphs of this chapter. I could not see a way beyond the idea of tools and techniques as a means to an end, with the only negligible influence they have on the result being the relative risk or certainty (see 4.1) with which they can realise a pre-existing intent. Worse still, whilst it’s easy to describe this stumbling block in retrospect, at the time it was far from obvious what my problem was.

Figure 2. 2 T-shape no.1



In each of these illustrations, the dark regions represent the body of knowledge I was most familiar with, and the lighter regions represent areas that I was aware of, but not yet wellversed in. As shown in Figure 2.2, at this early stage of the PhD, there was only a small field of literature I knew to explore. This field consisted of scholarly descriptions of designing and making, mostly from the fields of design studies, art history and craft theory (e.g. Cross 2007; Adamson 2007; Frayling 2012; Knott 2011; Smith 2010). But these were writers nearly always discussing things that had already been produced. Or, if they were discussing the design of things, it was almost always a materially disengaged exercise, performed through protocol studies (see, for examples, Purcell and Gero, 1998), or interviews. Each text seemed in a hurry to move away from the details of how a thing is designed and made. In the case of the more art history orientated texts I was reading, this was a movement away from the production of things, towards what they *tells us*, as a finished objects. In retrospect, I can ascribe this to what anthropologist Tim Ingold describes as a retrospective 'fixation with objects and images', over and above an 'appreciation of the material flows and currents of sensory awareness within which both ideas and things reciprocally take shape' (2011, p.10). But, again, at the time, and without the broader understanding I've since developed, it seemed like Pye had said all there was to be said about the relationship between designing and making. No matter how much of this literature I read then, the base of that "I" remained impermeable to me—there seemed no opportunity for its extension via a new contribution to this area (as seen in Figure 2.2, wherein there is no lighter region at the base of the "T"). I was unaware of "what else" could be known about the subject.

Main objective:

To develop an approach to my subject that can lead to a meaningful contribution to knowledge.

Key research questions:

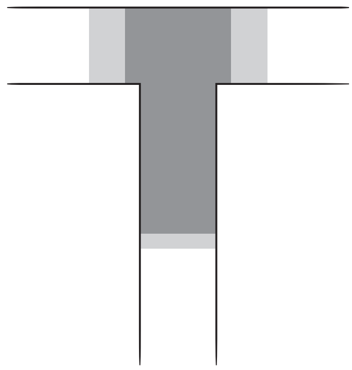
What influence, if any, do techniques of making have upon the process of design?

What theoretical approaches can help to understand the relationship of doing and thinking?

What other fields have looked into this subject?

2.5.2. Part Two

Figure 2. 3 T-shape no.2



Despite (or perhaps because of) his uncritical appropriation of Pye's ideas (see 2.1), it was reading Tim Ingold's work that began my exploration out into horizontal of the "T". Having been made aware of the book by my supervisor, and in no small part encouraged by its main title, I managed to negotiate a free review copy of Ingold's *Making: Anthropology, Archaeology, Art and Architecture* (2013a). The collection of essays it contains proved pivotal in the development of my PhD, and my own development as a researcher. In Figure 2.3, I illustrate this impact, showing how Ingold's book dramatically expanded the scope of my reading. As suggested by *Making's* subtitle, it is (in common with all Ingold's work) a book that both borrows from, and contributes to, a wide range of disciplines. Whilst it took me time to familiarize myself with Ingold's arguments (notice the dark region of Figure 2.3 has expanded only a little at this stage), it was this interdisciplinarity, and the idea that there was more to be said about the relationship between designing and making than I had previously recognized, that opened up new areas of exploration. I traced Ingold's citations back to their sources, and I sought out the work of his admirers and critics. In contrast to the relative paucity of insight I'd found in my previously narrow reading interests, here I began to discover ideas that helped me see design and making practices in a new light. Perhaps most importantly, this new body of literature began to suggest a possible methodology that would enable me to interrogate the influence of techniques on design practice (as illustrated by the lighter region that has emerged at the base of Figure 2.3).

<u>Main objective:</u>

To learn more about theories of distributed cognition/extended mind, in an effort to see how they might be applied to the study of designing and making.

Key research questions:

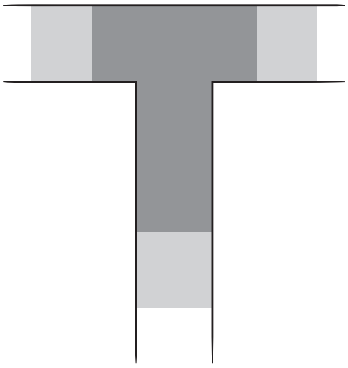
Could a “non-hylomorphic” (see 3.3.1) perspective on designing and making offer an insight into how techniques influence design processes?

How do David Pye’s declarations about the relationship of design and workmanship (see 4.1.8) stand up to Ingold’s work?

How do theories of extended mind correlate to my experience of designing and making practice?

2.5.3. Part Three

Figure 2. 4 T-shape no.3



Eventually, this reading and thinking led me to the situation illustrated by Figure 2.4. Having explored a never-ending web of citations and become more familiar with this broader spectrum of literature, I had found a theoretical foundation well-suited to my study. In work like Charles Keller and Janet Keller’s *Cognition and Tool use: The Blacksmith at Work* (1996), I saw examples not only of how to go about the first-hand study of tools and techniques, but also how the specific details of practical activity can inform, substantiate and illuminate more general ambitions. *Cognition and Tool Use* draws on Charles Keller’s experience as a blacksmith to contribute to the authors’ main field of interest—the anthropology of knowledge. It is grounded in the methods of situated action (see Suchman 1987), wherein research is conducted in real-world contexts and action itself, rather than an abstracted theory of plans guiding that action, is taken to be the primary focus. One of Keller and Keller’s key themes throughout their book is an attempt to understand the two-way relationships between a practitioner and their environment. By emphasizing the primacy of action, instead of planning and the role of intramental cognition, Keller and Keller are able to analyse how knowledge (their subject of interest) is distributed across a blacksmith and their workshop space, in the tools, techniques and materials they use. Whilst their main goal, to develop an 'anthropology of knowledge' (1996, p.159), is far removed from my own ambitions, Keller and Keller nonetheless provide an inspirational example of how concurrent thinking and making practices might be studied.

Main objective:

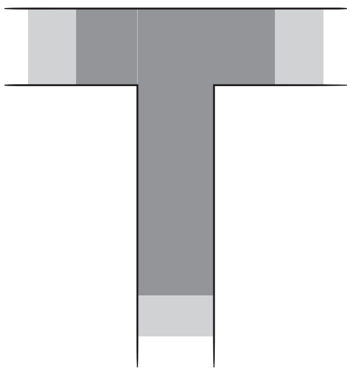
To explore how making techniques I'm familiar with can be understood not just as a means to an end, but as a way of working things out.

Key research question:

If we take seriously the argument that cognition is distributed across both people and things, what are the ways in which particular techniques structure and support decision making?

2.5.4. Part Four

Figure 2. 5 T-shape no.4



The transition between Figure 2.4 and Figure 2.5 can be described as a movement from a predominantly extra-disciplinary, literature-based approach, towards applying what I'd learned to my subject of interest. During this time, I began to document and analyse my first-hand experience with the techniques of designing and making. Informed by my newly discovered theoretical foundation, my aim was to study these techniques as ways of thinking. I was inspired by the idea of things being components of minds, and sought to understand what this might mean for design practice in the context of workshop practice. It was during this stage that I developed the idea of *epistemic character* (see 2.6.14 and Chapter 5)—a phrase I introduced to help understand what exactly I was trying to understand about tools and techniques. Although at first I had only the fuzziest idea of what

I meant by the phrase, naming my subject of interest helped to focus my documentation and analysis of practice. This is an aspect of what I was doing that a vague ascription to "reflective practice" would miss. I wasn't reflecting on every characteristic of, for example, using a ruler (5.1), carving a spoon (5.2), or making a paper aeroplane (5.3). I was specifically interested in how these techniques structure the process of working things out. Even though I had invented the phrase, I was at this stage interested in what "epistemic character" might mean.

Throughout this phase of the research, I was still reading as much as possible around my subject. My notebooks from the time are a combination of quotes, page references, drawings of tools, diagrams of "step-character" (5.2) and early attempts at writing studies like those found in Chapters 4, 5 and 6. That the later chapters of this thesis jump between the details of practice, and how these relate to broader theoretical points is likely a consequence of this approach.

It was also during this phase that I presented some of the ideas at conferences, introduced them to my teaching practice, and wrote a journal article (Luscombe 2018). The imperative to clarify my ideas for these purposes, and the modifications I have been able to make in response to their reception, have been very valuable.

<u>Main objective:</u>

To develop a rich account of how techniques might structure, support or potential compromise design processes, which draws upon the ideas of others and my practical studies.

<u>Key research question:</u>

What do I mean by *epistemic character*?

2.5.5. Part Five

Figure 2. 6 T-shape no.5

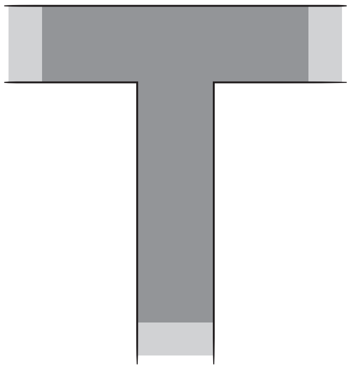


Figure 2.6 illustrates the stage I am at now, as I complete this thesis. The development from Figure 2.5 to this present situation is a consequence of trying to assemble my ideas into a coherent document. Through this process, previously vague ideas have become firmer, and I have happened upon new relationships between my work and that of others. I have realised that (in symmetry with this thesis' position on the making of designs), "ideas" do not really exist in advance of their realisation in words.

Creating this document has improved my awareness of the value of writing as a "construction", and how ideas may be woven together. I have also become increasingly aware of the potential for academic writing not to simply *tell its audience something specific*, but also to open up a line of enquiry that might be followed towards an insight. The most engaging, and useful, pieces of literature I've read have had this character. And I have tried to write this thesis with a similar aspiration.

In Figure 2.6, there remain light grey areas, which I would enjoy the opportunity to study further. One of the most important outcomes of my PhD, for me as a researcher, has been the expansion of my interests across the horizontal of the "T". By venturing out into unfamiliar disciplines, and then returning to my core subject and topic of interest, I have found a seemingly limitless source of inspiration. I hope that continued efforts in the same vein could help to further develop my contribution at the bottom of the "T".

<u>Main objective:</u>

To pull the research together into a coherent and valuable thesis.

Key research question:

How can the findings of this research be presented in a way that is academically rigorous and engaging to both design practitioners and researchers?

2.6. Research Method 2: An Exercise in Technology

Having introduced the first of my two research methods (a synthesis of interdisciplinary literature), and outlined its purpose (to lay a credible theoretical foundation for the study of techniques and help to inspire the analysis of those techniques), I will now describe the second of my methods. I call this an exercise in *technology*. This is to follow a lesser-known definition of the word (see 2.6.3), which takes it to be the comparative study of techniques. My studies of technique are first-hand, or what might be called practice-based, or an apprenticeship method (see Keller and Keller 1996; Marchand 2010a, 2010b). Put simply, I used techniques in my practice as a designer and teacher and reflected on the process. My means of reflection was to write and draw in notebooks. Owing to my concurrent literature-based approach, these notebooks are also littered with quotes, page references, and attempts at linking my experience of practice with the literature I was reading (see example pages in Appendix). This is why, as described in 1.3, I consider the writing "between" my two methods to have been crucial in forming the ideas and contributions themselves.

In this section, I will outline the ideas that guided my first-hand method. First, however, I describe the relationship between my literature review and practice-based methods, and highlight the theoretical foundation that underlies my study of techniques.

2.6.1. Overlap Methods

I believe the relationship between my two methods to be crucial. They 'overlap' (Guba 1981, p.86) in order to compensate for their potential failings, if they were to be followed in isolation. A purely first-hand study of techniques, conducted with no reference to existing literature might be hopelessly unguided, lacking the inspiration that comes from external influence. And an entirely literature-based approach (especially an interdisciplinary one) to this subject would risk becoming irrelevant, through a disengagement with practice, or techniques themselves. With the exception of Chapter 3, I have attempted to make clear this indissoluble relationship between my methods, by writing the thesis as an ongoing "conversation" between "theory" and "technique".

2.6.2. Theoretical Foundation for Studying Technique

The theoretical foundation developed for the research (described throughout Chapters 4, 5 and 6) has informed the following key features of my first-hand studies:

- It proposes that tools should be studied as part of active systems. Rather than studying tools in isolation, it emphasizes their role as part of systems that include practitioners, the materials being worked, and the other tools being used. This suggests a focus on *technique*, a subject I discuss below (2.6.3).
- It proposes that cognition is spread between the various parts of these systems. I introduce this idea in the following chapter (3.2).
- It acknowledges the potential for action to influence decision making. Below, I discuss how this commitment has led to my development of the concept of 'epistemic character' and how this has directed my analyses of techniques. In Chapters 3 and 4, I make clear my stance on the relationship of action and decision making.

2.6.3. Techniques as Systems

The word *technology* is typically used in the Anglophone world to refer to those objects and techniques that apply sophisticated, relatively novel scientific knowledge. As computer scientist Alan Kay pithily suggests, 'what people mean by the word *technology*, is anything invented since they were born' (quoted in Brand 1999, p.16)[9]. In French scholarship, however, *technologie* is a field of academic enquiry—it is the comparative study of techniques (Sigaut 1994; Audouze 2002; Salomon 1984). François Sigaut, who made the study of techniques a central part of his work as an historian and anthropologist, writes that '[t]echnology is to technics what linguistics is to language, biology to living beings, psychology to mental activity, epistemology to knowledge etc.' (1985, p.122)[10]. Just as biology studies living organisms, technology in this sense of the word is the science of techniques: 'its definite aim is to acquire knowledge on technics (i.e. on the technical activity of men), not to use or develop technics, at least not primarily' (ibid.). My studies of techniques can, under this definition, be considered an exercise in technology—an attempt to acquire knowledge on techniques. In several essays promoting his field, Sigaut offers

[9] As my guide on this subject, François Sigaut would have it though, 'attempting to separate [techniques] on the basis of scientific content is useless' (1985, p.118).

[10] Note that Sigaut here uses *technics* as a synonym of *techniques*. Whilst I reproduce this in the quote here, I use techniques throughout the thesis.

valuable advice its potentials and pitfalls. Of particular interest here is his discussion of the role of tools as parts of systems.

Sigaut himself was interested in understanding historic agriculture through the investigation of tools and techniques (see, for example, 1996) and was an enthusiastic advocate for this method of studying cultures through their technical practices. For Sigaut, a technologist should be interested in developing a thorough knowledge of the techniques themselves, before any attempts towards creating explanatory models. In criticism of simplistic agricultural histories, which failed to recognise the subtlety and variety of cultures across the world, Sigaut warns against using 'technology before being acquainted well enough with it' (ibid., p.427). In short, Sigaut considers many scholars, unsatisfied by technological studies that 'look so little rewarding by themselves', to be 'tempted to "use" them in support of supposedly more interesting aims as soon as they believe it possible' (ibid.). One of Sigaut's suggested methods for guarding against this over-eager appropriation is to ensure that 'you have gathered all that it is possible to know about a technique before using it for any "theoretical" purpose' (ibid.).

A common flaw in simplistic technology studies is, according to Sigaut, a misguided focus on tools themselves, over and above the activities of production (ibid.). Instead, Sigaut proposes that we should attempt to unite the study of artefacts with their use. An important strategy in this effort is to avoid assigning tools a fixed purpose, but to understand them as part of an activity. In a demonstration of this approach, Sigaut takes the example of a knife and claims that it should be considered not as something *for* cutting, but as something used *by* cutting (1994, p.430)[11]. For Sigaut's historical investigations, this reduces the risk of imposing contemporary ideas about the function of particular tools onto apparently analogous ones of the past. A collection of drawings of many different knives, each from a different time and place, illustrates this argument (ibid., p.431-2). Despite all having been categorized as 'knives', both the form and potential uses of these objects vary markedly. If we understand tools as used *by* their associated techniques, rather than *for* a specific operation, Sigaut argues that we may avoid inflecting analyses with misplaced preconceptions.

Unlike Sigaut, my concern is not with the interpretation of historical practice. His emphasis on techniques, however, still offers a useful insight into how to study tool use, particularly when considering the issue of *teleology*, or what tools are *for* (see 4.3.7). Sigaut's

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[11] A rudimentary translation assures me that Sigaut expands elsewhere on this idea, in French (1991).

determination to always describe tools in the context of their use is an effort to avoid simplistic accounts of function. For Sigaut, the problem with describing a knife as *for* cutting is that it discourages a sufficiently detailed investigation of the nature of 'cutting', and precludes the consideration of other operations a knife might be used for (stabbing, prying, splitting etc.). To instead describe the knife as used *by* cutting is an attempt to shift the emphasis towards the specifics of a technique, and to encourage studying the tool in that context. This critical approach to function has helped me to see beyond a purely pragmatic understanding of tools as a means to an end. I describe this position in detail in Chapter 4, but to summarise, it is through studying techniques in detail that I suggest we can become aware of the dual-purpose nature of tools, both as *for doing things to the world*, and *for finding out how those things are going*. Throughout Chapter 4, I draw on the example of hammering in a pin to develop the argument that, even in the simplest of operations, tools are both instruments for doing and for sensing feedback on our progress. This idea grounds the subsequent studies of epistemic character (the ways techniques structure the process of working things out).

Studies of 'technique' have thus become central to this thesis. Techniques involve a temporary coming together of tools, materials and practitioners: they involve movement and change that cannot be understood by studying tools in isolation, or just the eventual results of a process. Whilst I also discuss tools and materials throughout this thesis then, it is only within the contexts of their use—techniques—that they come to life as the subjects of study. This is a point well-illustrated by anthropologist Gregory Bateson when discussing the action of cutting down a tree. Bateson's ecological approach necessitates we pay attention to the indivisible system of 'trees-eyes-brain-muscles-axe-stroke-tree' (1973, p.318) when studying the process. Techniques can be understood as the link in such systems, between a practitioner, their tools and the materials they are working (see also Malafouris 2013).

2.6.4. The Difficulties of Technology

A recurring theme in Sigaut's work is his disappointment with regards the popularity of technology. Helpfully, he offers us an insight into why this might be the case, which, I believe, can illuminate a similar issue in studies of design.

Relative to other approaches in archaeology, anthropology and history, Sigaut considers the advancement of technology to have stagnated. As an advocate of the field, Sigaut argues that the situation requires a shift similar to that in botany or chemistry, which 'could only develop after it had been first decided that plants or substances should be studied for what they were, rather than what they were useful to' (1985, p.123). Where before plants and chemicals has been manipulated to achieve material ends, the sciences that grew out of these activities developed by assuming their study to be valuable for its own sake[12]. Sigaut's version of technology, wherein techniques become the object of study, requires a similar development.

Speculating on the reasons for the stagnation of technology, Sigaut suggests that it is due to a 'lack of people at once academically and technically trained' (ibid., p.124). Here Sigaut draws on the history of linguistics to illuminate the problem—observing that academics 'well acquainted with *belle lettres* might [have been] more or less reluctant to adopt the new point of view of linguistics, but at least they did not lack the minimum of basic skills and knowledge necessary to make their choice' (ibid.). Language was something all academics were familiar with, allowing them to understand, at least in principle, the value of studying it. 'On the other hand,' Sigaut continues, 'academics did completely lack this minimum of basic skills as far as technics was concerned' (ibid.). Without any knowledge of technical operations, Sigaut claims that scholars have repeatedly failed to acknowledge the potential value of technological investigations.

Despite some reservations regarding this claim (observations like Sigaut's appear to me a little too general), the effort to unite technical and academic knowledge is nonetheless an ambition I have shared throughout this research. And the theme of disconnection between academic thought and technical practice is one that I touch on in Chapter 3. Rather than make claims about the knowledge held by academic groups, however, I follow Knappett's and Ingold's approach to this issue, in sketching out the dualisms that pervade much thinking about material culture (see 3.2 and 3.3). The separation of mind and matter described by Knappett, for example, can be seen to relegate technical practice to the mere transcription of an antecedent idea. Under this model, the role of planning is promoted over and above material engagement and improvisation (see Ingold and Hallam 2007). And the influence of techniques upon the outcomes of practice is understood to be negligible. Unsatisfied by these internalist models, which, as I discuss (3.1), appear to dominate studies of designing and making, I have sought to follow Sigaut's lead and take techniques to be a subject of study. The underlying philosophy I have synthesised from other academic disciplines has enabled me to see beyond the assumptions typical of internalist approaches,

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[12] In the field of design studies, I suggest there has been a similarly pragmatic understanding of techniques (see Chapter 4), as means to an end, rather than a potential subject of inquiry.

and develop an approach to the subject of how techniques influence design practice from a novel, rigorous and, as I hope to show, valuable perspective.

Whilst, as I hope to have explained, I find Sigaut's discussion of technology a helpful inspiration, it should be noted that I do not anticipate a widespread redefinition of the term. I draw on the more obscure French usage here not out of an affection for things obscure and French, but because of its relevance to the research I am concerned with, and because of the methodological guidance Sigaut offers. As I have suggested elsewhere (Luscombe 2018), and hope to demonstrate throughout this thesis, I believe that a more widespread pursuit of "design technology" would be a worthwhile enterprise. It could help to sensitise practitioners to the ways in which their techniques structure, support, or potentially compromise their design processes.

In accord with Sigaut's advice to 'gather all that it is possible to know about a technique before using it for any such "theoretical" purpose' (1996, p.427), I have spent this study actually using the techniques I have studied. This has been my primary means to investigate what I mean by epistemic character, and how the epistemic character of particular techniques can be defined. This method has also been supplemented, however, by another valuable source of literature. Before explaining the methods of my first-hand studies, I'll briefly introduce this literature, and describe how it has been crucial in informing my understanding of technical competency.

2.6.5. The Technology of Practical Guidebooks

Throughout this research, whilst trying to engage in the kind of technology promoted by Sigaut, I have also drawn from a complementary body of work on techniques. I have studied sources that provide practical advice about how best to perform techniques. I include in this category of source material: instructional documentation provided with hardware and software; online forums for the discussion of practice; and books, periodicals and websites published to assist in the use tools and their associated techniques. Each of these sources has proved valuable throughout this PhD, by validating my use of techniques as competent, helping me to become familiar with new techniques, and helping me to contextualise when and why a technique might be used.

I have thus researched the techniques I describe throughout this thesis by both employing them myself, and studying the theory of their use. Both strategies have helped to deepen my knowledge of making practice. Sometimes the literature has affirmed that which I knew already, and sometimes it has opened my eyes to alternative approaches.

This kind of information about productive techniques has been published for centuries. Historic examples include Joseph Moxton's *Mechanick Exercises: or the Doctrine of Handyworks* (1703), André-Jacques Roubo, *L'Art du Menuisier* Paris, (1769) (see also the translation by Williams et al, 2017), and Bertrand's *Descriptions des Arts et Métiers* (1783). These authors wrote on the subject of technical activity not as an academic pursuit, but in the service of other "technicians", to provide instruction and advice.

To this day, a wealth of resources is published in the service of practitioners aiming to improve their understanding and application of making techniques (e.g. Hayward 2016; Sellers 2016; Watson 1982) (see, for a history, Knott 2015). Most often written or presented (in the case of instructional videos) by people who have acquired knowledge on techniques through their own practice, such work is intended to advise those looking to improve their skills.

Although, as Tim Ingold observes, there might be a popular mythology surrounding the 'tacit knowledge' of 'the silent craftsman who is struck dumb when asked to tell of what he does, or how he does it', in their interactions with anthropologists, real-life skilled practitioners are 'often inclined to expound upon their crafts vociferously, demonstrably and at very great length' (2013a, p.109). In my experience, such expounding is also easily found in print.

2.6.6. Techniques Studied

The techniques studied during this research are (in the order they appear throughout this thesis):

- Hammering a panel pin (see Chapter 4 and 6.2)
- Using dividers (see 5.1)
- Using a ruler (see 5.1)
- Carving a spoon using a saw, an axe and knives (see 5.2)
- Designing and making paper aeroplanes (see 5.3)
- Using a panel saw (see 6.3)
- Using a radial arm crosscut saw (see 6.3)
- Using a nail gun (see 6.3.3)
- Using a metal file (see 6.4.1)
- Using a belt linisher (see 6.4.1)
- Using a bench plane (see 6.4.2)
- Using a (timber) thicknesser (see 6.4.2)
- A series of techniques for prototyping staked furniture (see 6.5)
- Using a spokeshave (see 6.6)
- Using a coping saw (see 6.6)

This collection of techniques has served a dual purpose. Firstly, their study has helped me to think through the idea of epistemic character, and how it may be understood and applied. The three aspects of epistemic character I discuss in Chapter 5 were developed and tested with respect to these techniques. Second, the range of techniques provides me with a way to illustrate the contributions of this thesis, and show how investigations of epistemic character can be performed more generally.

The selection criteria for the techniques were as follows:

<u>Accessibility</u>

Each technique had to be accessible enough for me to use, and re-use, as often as I felt necessary. This reduced the pressure on my recording methods (see 2.6.7), and enabled me to revisit a particular technique if, in light my developing understanding of epistemic character, I wanted to reflect on another aspect of its nature. Inevitably, this criterion reduced the variety of techniques I was able to study (see 2.6.6).

<u>Brevity</u>

To further enable me to revisit techniques, each one had to be a brief operation. A sawing or hammering task, for example, can be completed in seconds. This brevity also suited the micro-level perspective (see 2.6.12) I adopted towards the techniques.

<u>Competency</u>

So that I could write about each technique from a knowledgeable perspective, I was sure to select only those for which I had a pre-existing competency and confidence that I was using a widely-acknowledged approach (2.6.8). Choosing techniques that I had no experience of would have left me struggling to become proficient, instead of reflecting on the ways they might structure design processes. As I discuss in Chapter 7 (see 7.2.2), studying the epistemic character of unfamiliar techniques would perhaps be best achieved through collaboration with a knowledgeable practitioner in the relevant field.

<u>Range</u>

For the purposes of illustrating the contributions of this thesis, I sought to work with a range of techniques across different material disciplines. These range from the techniques of design drawing (the rulers and dividers of 5.1), to woodworking and metalworking techniques. I believe this strategy helps to demonstrate how the ideas are applicable across different fields of practice.

Comparative Value

A recurring feature of most studies in this thesis is the comparison of two similar techniques, in order to identify the differences in their epistemic character. I have found this to be a useful means of both determining what contributes to epistemic character, and also describing it to others. The first of these comparisons, for example, considers the difference between using rulers and dividers as instruments for design. Considering whether a particular technique has a useful ‘counter-technique’, was thus an important criterion for selection. It should be noted, however, that whilst this approach was valuable in developing the contributions of this thesis, having two comparative techniques would not be a requirement of subsequent studies of epistemic character.

2.6.7. Recording Methods

The primary means of recording the details and insights from my first-hand studies was reflective note-taking (see Appendix for scans of notebooks). This was done either during, or shortly after the event. Owing to the accessibility and brevity (see 2.6.6) of the techniques studied, the demands on “capturing” the details of practice were reduced—I always had the opportunity to revisit the techniques, in order to refine my thinking about their specific character, and the notion of epistemic character more generally. This can be considered an instance of what Guba calls ‘persistent observation’, where ‘[e]xtended interaction with a situation or a milieu leads inquirers to an understanding of what is essential or characteristic of it’ (1981, p.85). As I discuss in Chapter 7 (see 7.2.3), if future studies were to investigate less accessible and more prolonged techniques or operational chains, the demands on recording methods would likely be increased. For the purposes of the studies document here, however, note-taking provided a comprehensive and unobtrusive means of reflecting on practice.

Whilst not part of a preconceived methodological strategy, the fact that I made these notes in the same books in which I was simultaneously taking notes from other literature, attempting to develop my ideas about epistemic character, and write drafts of this thesis, has doubtless affected the content and presentation of the research (see Appendix for scans of the notebooks). It is for this reason that I consider writing as the bridge between my two methods of inquiry (see 1.3 and 2.3). The series of notebooks produced during this research are largely filled with attempts at pulling together insights from technical practice and those from literature.

The line drawings of techniques-in-use have been created by tracing photographs using Adobe Illustrator. Once the content of each chapter had been developed, I determined what images would helpfully illustrate the text, and took the necessary photographs. This approach was inspired by instructional books of craft practice (e.g. Galbert 2015; Watson 1982; Sundqvist 1990), which use text and images to communicate complex guidance about tools, techniques and materials.

These post-hoc illustrations were only made possible by the accessibility and brevity (see 2.6.6) of the techniques studied—this strategy would have to be revised if future work aims to study more complex operations that could not easily be repeated. It should also be noted that the original photos (a selection of which are presented in the Appendix) were not something that I used for any analytical purpose—though again, the use of photography or video might be a valuable documentary method when dealing with greater complexity (see 7.2.3).

2.6.8. Competent Tool Use

I have been eager, throughout this research, to ensure that I have practiced and described techniques in accord with well-recognised approaches. In a discussion of hammering a pin in Chapter 4, for example, I describe how one end of the head of a specific kind of hammer—the Warrington pattern—is typically used to first set the pin, before the other end of the hammerhead is used to drive the pin home. In this, and all the other descriptions of tool use, I have sought to analyse widely acknowledged techniques. Although I appreciate both experienced and novice practitioners may have idiosyncratic habits when using certain tools and techniques, my studies are grounded in what I have established to be ordinary, competent practice[13]. The sources of technical guidance introduced above (2.6.5) have been key in validating this approach, and I cite them alongside my descriptions of practice. This particular approach to hammering, for example, is described in Aldren Watson's popular book *Hand Tools: Their Ways and Workings* (1985).

[13] I see no reason, however, for idiosyncratic techniques to be precluded from the kinds of analyses I present in Chapters 4, 5 and 6, but for this thesis, I have aimed to stick to straightforward techniques.

2.6.9. Expertise

None of the procedures I describe throughout this thesis are particularly complicated in theory or practice. Hammering in a pin (4.1), using a pair of dividers (5.1), or carving a wooden spoon (5.2) (to use three of my examples) are all tasks that, with instruction and a little practice, could be successfully completed by a novice. Whilst I acknowledge that there are differences in the efficiency and outcomes of novices compared to those who are highly skilled, the features of technique I am interested in remain the same. Even though, as philosopher Hubert Dreyfus describes, the once explicit procedures of a process might eventually be performed intuitively by a well-practiced expert (2002), the same identifiable characteristics of a technique remain[14]. Both ends of the Warrington hammer, to continue the example, will still be used. And all practitioners, however skilled, will have to take multiple strikes to hammer in the pin. As Ingold's statement about craftspeople being very able to talk about their work illustrates, these characteristics can be identified within periods of practice, either through self-reflection, or third-party observation. Indeed, the very existence of instructional literature, in which techniques are explicated clearly and systematically, demonstrates that there is much that can be described, shared and analysed. This is a record of what sociologist Harry Collins' calls 'interactional expertise', a kind of knowing that sits between formal knowledge (as in rules, formulae and facts) and informal, or tacit knowledge (2004). Collins introduces this third kind of knowledge to make the point that 'it is possible to learn to say everything that can be said about bicycle-riding, car-driving or the use of a stick by a blind man, without ever having ridden a bike, driven a car, or been blind and used a stick' (2004, p.127). Although I have actually used the techniques discussed throughout the thesis then, I make this point to be clear that my analyses do not depend only on the specifics of an idiosyncratic approach—they correspond to an existing body of "interactional" knowledge.

2.6.10. Techniques Embedded in a Context

In addition to validating my studies of technique, sources of technical advice have also allowed me to contextualise, if necessary, when and why a certain process might be used. Whilst most of the studies of technique I present throughout this thesis are removed from longer sequences of production (the hammered pin is not joining anything in particular, for

[14] On this idea, cognitive scientist John Sutton is wary of subscribing totally to the idea of unconscious, non-rule governed expertise, wherein the maxims associated with developing skills are discarded. In a study of professional cricketers, he shows that maxims continue to act as 'instructional nudges' (2007, p.773-4)

example), it has at times been useful to describe why a practitioner might choose one technique over another, or to at least acknowledge that the process I describe is one of several possible approaches. This is an idea promoted by Siguat's version of technology—just as the focus on techniques shifts attention away from isolated artefacts, and towards systems of use, it also encourages the examination of those systems in a broader setting[15]. As observed by archaeologists Sillar and Tite, techniques are always 'embedded' in a particular context (2000, p.12). Technical practice is not just informed by material constraints, but also by 'wider environmental, technological, economic, social, and ideological practices' (ibid., p.17).

2.6.11. The Limits of The Context

For each technique I study, I suggest where it might sit in a "*chaine opertoire*", or "operational sequence" (the archaeological term for a sequence of techniques: see Leroi-Gourhan 1993; Conneller 2011). The technique of hammering a pin, for example (see Chapter 4), is described with reference to joining pieces of wood together[16]. Beyond this local contextualization, however, most of the studies presented here do not place techniques within longer chains of operations[17], or a within a wider social context. This focused approach has enabled the research to take what archaeologist Lambros Malafouris calls a 'micro-level perspective' (2013, p.224; see 2.6.12) on practice. When founded on the idea that cognition is distributed across both people and things, Malafouris has shown that such isolated studies can yield valuable insights into how techniques might structure thought and action (2008). Methodologically, limiting the boundaries of the studies in this way has focused my attention on the nature of the techniques themselves, rather than any associated social context. In support of a theme that runs throughout the thesis, I also believe that this approach helps to demonstrate the value of studying technical practice in its own right. As I discuss in Chapter 5, paying careful attention to the details of techniques allows us to take seriously the role they might play as extensions of minds.

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[15] Sigaut himself sees techniques as subsidiaries to 'operations'—they can be considered 'alternative ways of carrying out a given operation' (1994, p.435).

[16] Such tightly bounded contexts are typical of studies of "situated action" (see 3.2.4), which as anthropologist Bonnie Nardi (critically) suggests, are inclined to take the situation for granted, without acknowledging that it is part of a larger activity (1996, see especially p.45). I have done this consciously, to suit the purposes of my research.

[17] The exception to this is the investigation of staked furniture prototyping (see 6.5), which considers a longer sequence of techniques to discuss how decisions may be distributed throughout a design process.

Given this narrow focus, it is worth acknowledging those aspects of designing and making activity that I have consciously excluded through the method used here.

Collaboration

Perhaps the most notable feature of real-life practice missing from this research is collaboration between people. My studies are focused upon the relationship between a single practitioner and the tools and materials of a technique. Given the adoption of a distributed understanding of cognition, this might seem a strange omission. Indeed, Edwin Hutchin's pioneering study of distributed cognition on board naval vessels (1996; see 3.2.4) famously looked at how the knowledge necessary for navigation was not held centrally, either by an individual crew member or piece of equipment, but spread across the whole system (see p.219). Here the interactions between people (see, for example, p.237-9) were as much the subject of investigation as the interactions with artefacts (see, for example, p.96-102). As described above, my decision to avoid this macro-level perspective on practice was a tactic intended to excavate the details of a practitioner's relationship with tools and materials, in a way that would have been difficult to achieve if I were also trying to understand the intricacies of conversation between people. Rather than seeing the work in this thesis as somehow incongruous with the study of collaboration, however, I believe the research presented here is well-placed to be extended into other contexts in the future. This is a point I discuss in Chapter 7 (see 7.2).

Alternative Approaches

As described in 2.6.8., I have practiced and analysed only instances of 'competent tool use'. By this, I mean well-recognised approaches to operations that follow an uncontroversial process. Another feature of 'real-world' practice that this research therefore excludes is the alternative approaches to operations that might vary between people, communities and cultures. In my description of sawing (see 6.3.1), for example, I document the use of a Western panel saw. Western saws differ to their Japanese counterparts in that their teeth are sharpened to cut on the push stroke, rather than the pull stroke. This simple difference has a multitude of implications for the practice of woodworking, from the kind of structure necessary to hold the workpiece in place, to the ease of sighting the cut line as it fills with dust, and the kinds of wood joints a practitioner might be inclined to employ.

In addition to these widespread alternative approaches, there are likely to be many more idiosyncratic techniques that a broader study of other practitioners would reveal. Whilst such varied processes would doubtless be fascinating in terms of their epistemic characters, I have avoided their study during the course of this research. The reasoning behind this was to avoid any controversy regarding my descriptions of techniques (and whether they represent 'best' practice), and instead focus on my developing understanding of epistemic character. I have sought to keep the details of the studies as ordinary as possible, whilst analysing them in an extra-ordinary way.

Variety of Techniques

Because the techniques I study are those that I am familiar with, and are accessible within the environment the research has taken place (see 1.5), I present a limited range of techniques. The ambition has not been to undertake a comprehensive survey of designing and making techniques, but to interrogate a small selection in order to develop and define the idea of epistemic character, and demonstrate how it may be applied. In Chapter 7, I discuss how, by building on the foundation of this thesis, a wider variety of practices could be subject to further research (see 7.2.2).

2.6.12. Chrono-architectures

Having introduced the idea of studying techniques, I now describe my approach in more detail. This continues the theme of delineating the terms of my engagement with techniques. On this, I follow archaeologist Lambros Malafouris' micro-level perspective:

> 'On the one hand, pottery making, when seen from what previously was called a macro-level perspective, can certainly be classified as a voluntary rather than a passive act—the potter certainly intends to perform a sequence of goal-directed bodily movements aimed at producing a pot. On the other hand, when seen from a micro-level perspective, pottery making, as a demanding skilled action, can be described as a dynamic chain of voluntary, passive, and reflexive action elements' (2013, p.224)

Throughout his book, *How Things Shape Mind* (2013), Malafouris develops a criticism of his discipline in similar terms to Carl Knappett's. Drawing on the idea of distributed cognition and the theory of extended mind (see 3.2), Malafouris presents studies of practice (such as the pottery example introduced by the quote above) that aim to redress the internalist approach to cognition. The micro-level perspective he adopts is crucial to explore how 'material agency' (ibid., p.209-226, see 5.3) and the temporal arrangement of techniques influence the outcomes of practice. He calls the associated stance towards human thought, action and production *material engagement theory.* I discuss the details of Malafouris' approach, as well as the ideas of distributed cognition and extended mind in the following chapter (see 3.2.3). An aspect of his work relevant to the present discussion of my method, however, is his concept of *chrono-architectures*.

For Malafouris, the chrono-architecture, or ‘temporal anatomy’ (ibid., p.222) of a technique relates to how it is arranged in time. It is the dynamic chain of actions involved throughout a process. Malafouris writes that ‘in order to understand creative agency we have to understand the temporality of creative action’ (ibid., p.213). The chrono-architecture of a technique thus aims to describe the roles played by the agencies of a practitioner and their tools and materials over time. Defining the limits and granularity appropriate for such studies necessitates that ‘we carefully define the portion of time encapsulating the event we want to describe and then decide whether this portion of time constitutes a meaningful event in the larger enchainment of events constituting the activity we seek to explain. This is necessary if we want our account of the causal hierarchy of events not to trivialize the complexities of their cognitive ecology’ (ibid., p.223). In my studies, I have been similarly mindful regarding what constitutes a “step” of production, and when identifying where significant decision making takes place (see Chapters 5 and 6, especially 5.2).

2.6.13. The Unit of Analysis in Ethnography

As in Malafouris’ work above, determining the appropriate unit of analysis has long been a concern for studies of cognition. By tracing the antecedents of theories of cognition in the field of Computer Supported Collaborative Work (CSCW), information science researcher Gerry Stahl summarises a historical shift in focus, from the individual towards social systems (2011). From Socrates (born c.470 BCE) until Hegel (born 1770), Stahl describes how ‘cognition was assumed to be an innate function of the individual human mind’ (ibid., p.194). Post-Hegel, Stahl observes how social relations have become included in the unit of analysis.

For fields such as CSCW, with its frequent interest in interactions between people (in addition to interactions with artefacts), this socially-minded view of cognition is fundamental. As Stahl observes (ibid.), there are range of theoretical approaches that underpin much of the work in this area. These include a selection that have also informed this research: Edwin Hutchins *Distributed Cognition* (see 2.6.11 and 3.2.4); Lucy Suchman’s *Situated Cognition* (see 3.2.4); and (owing to its potential relevance for an extension of this research), Bruno Latour’s *Actor Network Theory* (see 7.2.1).

As I describe in Chapter 7, if post-doctoral work were to expand the unit of analysis to include collaborative, more complex studies, the ethnographic approaches that inform

CSCW and Science and Technology Studies (STS) would provide an effective foundation (7.2.1). According to the micro-level perspective I adopt for the studies in this thesis, however, I have not benefitted from the potential of these approaches to guide analyses of multi-participant contexts. Instead (thanks to its simultaneously methodological and thematic relevance) the most inspirational piece of ethnography I have read throughout this research has been *Cognition and Tool Use: The Blacksmith at Work,* by anthropologists Charles Keller and Janet Keller (1996). As I discuss in 2.5.3, 5.2.1, and 5.3.1, Keller and Keller use a first-hand study of blacksmithing to understand how cognition is distributed across a workshop—in the tools, techniques, materials and the practitioner themselves. Grounded in the 'situated' approaches to cognition developed by Suchman (1987) and Jean Lave (Lave and Wenger 1991)[18], Keller and Keller's work promotes the study of action, over mental representations. On the subject of units of analysis, however, they follow a more focussed perspective than others working within these frameworks might. Comparing their work to the 'activity theory' approach of Engeström (1993; see also Stahl 2011), Keller and Keller describe how 'Engeström focuses on the system in sociohistorical development, while it is our task to account for the accomplishments of a person acting within such a system' (1996, p.110). This focus on individual accomplishment is what differentiates Keller and Keller's study from much work on situated action. Owing also to its first-hand, apprenticeship-based method, and the nature of the craft studied, Keller and Keller's work has offered a valuable ethnographic guide in how to interrogate practice.

One aspect of Keller and Keller's work that has been particularly influential to this research is their use of the 'heats' of blacksmithing, as a means to inform an analytical strategy. A heat is a period of time in which, once removed from the forge, a piece of hot iron remains workable. Once it has cooled and lost the requisite malleability, the heat ends and it is returned to the forge (p.110-11). By using this fact of practice as a marker for how they delineate the steps of production—for how they how they determine the units of analysis—Keller and Keller's study was crucial when developing my analyses of step-character (see 5.2.1).

2.6.14. A Definition of Epistemic Character

As described above (see 2.5.4), the reflective nature of my first-hand studies has been guided by the concept of epistemic character. This was predominantly influenced by Kirsh and Maglio's concept of *epistemic action* (1994) (see 4.2). When in its embryonic state, I

[18] Lave is another influential theoretician in CSCW, as cited by Stahl 2011

didn't really know what I meant by the term. But it's meaning, significance, and the means by which it may be studied have evolved alongside my studies. This was not a sudden revelation, but came about through my 'persistent observations' (Guba 1981, p.85; see 2.6.7). Through exposure to a diverse range of techniques in the workshop setting of my design and teaching practice, and through continual reading and attempts at writing, a more precise concept of what I meant by epistemic action became apparent. I have developed a definition of the term:

Epistemic character is a property of a technique. It structures the process of working things out whilst using the technique.

I have used the verb "to structure" because it may apply to both the temporal and physical arrangement of the technique (an idea inspired by Malafouris' chrono-architectures), and alludes to the structure of a cognitive system. In Chapters 5, 6 and 7 I elaborate on this definition, by suggesting how we may investigate the epistemic character of techniques and considering the significance of the concept. An important aspect of this definition (worth noting before the following chapter on 'Designing and Making') is that it does not discriminate between techniques usually considered "design techniques" (e.g. drawing with a ruler, see 5.1.6) and those usually considered "making techniques" (e.g. using a bench plane, see 6.4.2).

2.7. Summary

Although I have presented what I consider the key features of my methodology in this chapter, and described its development, there remain aspects of my theoretical foundation that have yet to be clarified. In particular, I have alluded to the topics of "distributed cognition" and "the extended mind", without providing much detail on what I mean. This is a situation I rectify in the following chapter, where I introduce the ideas by weaving them into a narrative about the relationship between designing and making.

This point returns us to where this chapter began—the intertwined nature of my questions and methodology. It should be noted that the entwinement of methodology, theory and practice continues on into this thesis. Whilst I have presented two discrete methods of investigation here, I also hope to have made clear (through my "chronology") that these two approaches are deeply connected. In an effort to capture this interrelatedness, I do not present the thesis in a linear "Literature Review – Data Gathering Phase – Analysis" format. As I have described above, I hope that the structure of this document can communicate not just the "findings" of my research, but also be suggestive of how these ideas have presented themselves to me, along the way. Later chapters therefore continue to introduce new theoretical ideas alongside studies of practice. Also in this spirit, the next chapter critiques the relationship of designing and making, through a discussion that attempts to recall my dawning appreciation for alternative understandings of creative activity.

3. Designing and Making

Throughout this chapter, I consider the relationship between designing and making. I begin at a time often associated with their division—in the Fifteenth Century, with the publication of Leon Battista Alberti's architectural treatise, *De re aedificatoria* (1452). Alberti is widely credited with defining, for the first time, the role of the architect as distinct from that of the master mason. Where before building practice had been directed on-the-ground, by a figure in and amongst their materials and men, Alberti defined architecture as a chiefly representational practice, its goal being the creation of plans for others to follow.

I then travel forward through time, to the early days of "design science" and the work of Bruce Archer at the Royal College of Art. Through the example of Archer and others, I identify that the theoretical distinction of designing and making remains an implicit feature of design studies. In making this claim, I am not alone. I explore the pioneering work of Henrik Gedenryd, who demonstrates that this dualism of designing and making is a result of design theory's adoption of an "internalist" model of cognition. Gedenryd argues instead for an approach to design (and cognition more generally) that does not draw such a sharp distinction between thinking (designing) and acting (making). This leads us to theories from the disciplines of anthropology, archaeology, science & technology studies and cognitive science, all of which promote "extended", "materially-engaged", and "distributed" models of cognition. The key idea is that thinking doesn't just happen "in the head", but goes on between people and things. As I hope to show throughout this chapter (and the rest of this thesis), such ideas shed new light on the relationship between designing and making, and offer a valuable perspective from which to interrogate the influence of technique on design practice.

The final section of this chapter presents two philosophies of design. The first underlies Alberti's distinction—it takes matter to be inert and receptive to a designer's wishes. The alternative philosophy of design promotes the heterogeneity of the material world, its active and emergent nature, and the resulting demand for improvisation. I describe how philosophers have associated each of these models of production with an archetypal figure, by contrasting the "architect" with the "artisan". Although I'm wary of imposing this dichotomy (a point discussed with reference to the idea of "craft"), I believe these discussions offer a useful corrective to prevailing understandings of production. And, in making the case for a richer understanding of practitioners' engagement with materials, tools and techniques I suggest an "artisanal" philosophy can helpfully inform my research.

3.1. How are things designed?

> '[W]e shall call the Design a firm and graceful pre-ordering of the Lines and Angles, conceived in the Mind, and contrived by an ingenious Artist.' (Alberti 1452 [translated 1785], p.27])

3.1.1. Leon Battista Alberti

In *A History of Architectural Theory* (1994), Hanno-Walter Kruft introduces the work of architect and renowned Renaissance figure Leon Battista Alberti. On the evidence of his ten-volume architectural treatise, *De re aedificatoria*, Alberti is widely credited with being the first writer to distinguish the role of an architect from that of the builder (see, for example, Hanson, 2013, see p.3). The architect was responsible, according to Alberti, for creating the 'Design'—that 'firm and graceful pre-ordering of the Lines and Angles' in the quote above. With this came an important theoretical distinction, between the design for a building and its subsequent material realisation. As Kruft observes, Alberti believed 'that the architectural idea is crystallised in the drawn design. In both his theory and practice, design and execution were divorced from one another' (1994, p.48-9).

The aim of this chapter is not to dispute definitions of 'design'. In agreement with design theorist Richard Buchanan, I believe such 'battles' to be 'fruitless' (2004, quoted in Per Galle 2011, p.92). But I also follow Buchanan's observation that definitions nonetheless 'serve the purpose of shaping a particular line of inquiry' (ibid.). My particular line of inquiry demands that I consider the relationship between designing and making in detail. And it is the nature of this relationship that Alberti defined.

The model of production that underlies Alberti's definition is a widely-held account of how things are designed and made. 'This is to start', writes anthropologist Tim Ingold, 'with an idea in mind, of what we want to achieve, and with a supply of the raw material needed to achieve it. And it is to finish at the moment when the material has taken on the intended form' (2013a, p.20). On this understanding, making is considered an activity wherein ideas (or designs) internal to the mind are projected outwards, upon a world of materials. The problem with this understanding, and the central theme of the criticisms I draw together below, is that it fails to account for the role of material engagement in the processes of production. 'Time and again', observes Ingold, 'scholars have written as though to have a design for a thing, you already have the thing itself' (2013, p.22). In the academic study of art, or in the field of archaeology, this model of production leads to objects being treated as indices of their makers' intentions (see also Knappett 2005 and 2.3.1). In the study of design, I argue that it obscures the value of, and inhibits the study of, making practices.

My aim is not to entirely refute Alberti's definition of design, or become embroiled in an intractable debate about what is and is not designing. With reference to interdisciplinary literature on the subject, however, I hope to explore how a less binary distinction between acts of designing and making could enable a greater understanding of the influence of tools and techniques on design processes. For whilst Alberti's model is perpetuated in prevailing accounts of design, it is not without criticism. And, as I hope to show, some of these criticisms provide a valuable theoretical basis from which my later explorations of epistemic character can proceed.

3.1.2. Alberti vs. The Gothic

As architectural historian Robert Tavernor discusses, Alberti's own buildings were actually made via a somewhat compromised version of his ideal model—concessions had to be made both to material constraints and throughout the negotiations necessary in the politics of his era (1998, see p.201-2). But the underlying philosophy still took hold. In the practice of contemporary architects, we can see the enduring success of Alberti's attempt to elevate the role of planning, and the creation of drawn specifications in advance of construction (see for example, Eisenman 1999).

The role of drawing in Alberti's theory diverged from that of the Gothic era. As architect Lars Spuybroek discusses, when master masons were directing the construction of Gothic cathedrals, they created drawings that operated in a *descriptive*, rather than a *prescriptive* way (2011, p.18). Drawings did not aim to specify the subsequent built work in detail, nor were they all made in advance. Often, drawings would be created throughout the construction work; some drafted on paper, but 'also cut into wood and carved into stone floors' (ibid.). A small number of these carvings can still be found incised into the floors of the buildings themselves (p.18). To most modern architects or builders, such drawings would seem incomplete, offering too little detail, especially when considered in relation to the elaborate carvings and tracery that they preceded (see Turnbull 1993; Ingold 2010, see p.93). It was against this backdrop, following centuries throughout which buildings were not tightly-specified in advance, that Alberti's definition of design was formulated. Whilst it might seem like common sense now, the delineation between a design and its execution was thus a point worth making.

3.1.3. Bruce Archer

Jumping forward in time, Alberti's model of production has been expressed more recently by other prominent design theorists. One example of this legacy can be found in the early work of Bruce Archer. Archer worked for 27 years at the Royal College of Art (RCA), and can be considered a key figure in the history of design studies. Prior to the early 1970s, when he was promoted to the role of Research Professor in the RCA's Department of Design Research, Archer had spent time as a mechanical engineer, a lecturer, and was involved in research projects at the college (Boyd David and Gristwood 2016). Articles published throughout these early years at the RCA were later assembled into Archer's 1968 PhD thesis, *The Structure of Design Processes* (1968). It is to a recent discussion of the formulation, achievements and failings of this thesis (Boyd Davis & Gristwood 2016) that I now turn. I draw on Archer's work in order to demonstrate the continuing separation of designing and making in studies of design.

In accord with other publications of the era (for example, Alexander, 1964; Simon, 1969; Jones, 1970), Archer's thesis can be seen as an attempt to create a generalised model of design processes. It was a project in the nascent "science of design", which has since exerted a profound influence on the direction of design studies (Dorst 2006; Cross 2001). Whilst I am chiefly interested in Archer's conception of the relationship between designing and making, I first introduce his idea that design problems should be fully defined in advance of design practice. I will then discuss how, of these two aspects of Archer's ideas, the claim about the definability of design problems has since been eroded, yet the distinction he draws between designing and making largely remains an implicit feature of design studies.

<u>Archer on Solution Spaces</u>

'An important feature' in Archer's model of design, write Boyd Davis and Gristwood, is the 'calculation of the solution space within which the final design must lie' (2016, p.9). Archer proposes that design work should proceed by first 'defining the brief, establishing the requirements and giving them appropriate weights, securing the necessary data and then actually designing' (ibid.). In this model, the parameters of a project are to be determined before the design work can begin. Designers are expected to know all that can be known about their problem, so that they may then design a respondent solution.

Despite Archer's promotion of this ideal, Boyd Davis and Gristwood identify that even parts of his own thesis appear skeptical as to its practical possibility. In later passages of the work, Boyd Davis and Gristwood consider Archer to undermine key aspects of his model, in admissions such as: '[t]he complete set of objectives is only rarely definable at the beginning of the project.' (Archer 1968: 6:15), and 'any effective design procedure must therefore permit radical reappraisal of the problem at any stage.' (Archer 1968: 6:17) (both quoted in Boyd Davis and Gristwood 2016, p.11). Speculating as to the source of these seeming inconsistencies, Boyd Davis and Gristwood suggest that it was perhaps Archer's latter experience of the 'messiness' of real world design (ibid., p.10) that would have suggested the problems in his model. As in Tavernor's analysis of Alberti's architectural practice (1998, see 3.1.2), Archer's theory didn't quite harmonise with the reality. Although still committed to the ideals of his system, Archer's apparently conflicted thinking on this issue was a sign of things to come.

3.1.4. A Messier Reality

More recently in design studies, the conflict present within Archer's thesis has been abandoned, in acceptance of a messier reality. The assertion that that there can be a well-defined 'solution space' in advance of design work has given way to the idea that there is a co-evolution of design problems and solutions (Dorst and Cross 2001). Rather than determining all requirements in advance, this idea accounts for the inevitability of new requirements emerging throughout the process. Archer's ideal has thus been criticized for being too linear an approach. Such criticism is typical of those levelled at early projects in the science of design, where overtly rational or positivist approaches to the subject have fallen out of favour, in the face of real-world complexity (Cross 2001, see p.53-4; Dorst 2006; Per Galle 2011, see p.82-4). Where idealised design processes were once drawn with straight lines and arrows pointing in one direction, they now as likely to rely on curves, lines that might double back on themselves, overlaps and fuzzy bits (see, for example Badke-Schaub & Frankenberger 2004, p.123). Or else, as in the case of Christopher Alexander, a pioneer (and equally pioneering sceptic) of early design studies (see Bayazit 2004), diagrams have been forsaken altogether (see, for example, Alexander 1979).

The field of design studies has thus retreated from the idea that there can be a well-defined set of requirements drawn up in advance of a design project. In all but the simplest of design challenges, such an aspiration has been shown to be impractical. In what follows, however, I aim to show how Archer's similarly linear interpretation of the relationship between designing and making has remained an implicit assumption of the field[1].

<u>Archer on Designing and Making</u>

'A key element in the act of designing', Archer claimed in one of a series of 1963 articles, 'is the formation of a prescription or model for a finished work in advance of its embodiment.' (Archer 1963, p.70, quoted in Boyd Davis and Gristwood 2016, p.9). In this

[1] I discuss the limited number of exceptions to this claim in 3.2.1

assertion, we find the same distinction of designing and making that Alberti had committed to paper over 500 years before.

The article thus went on to declare that ‘a sculptor working directly with his or her material is not designing, but “when a sculptor produces a cartoon for his proposed work, only then he can be said to be designing it”’ (Boyd Davis and Gristwood 2016, p.9-10). In another, even more contorted attempt to see this logic through, Boyd Davis and Gristwood describe how it leads Archer to the ‘odd contention that a couturier is designing even when making a garment on the stand—but only provided this is not the finished item but a prototype for a garment that is going to be made subsequently’ (ibid., p.10, footnote 10).

Ignoring the strange lengths Archer goes to in order to maintain the theoretical distinction of designing and making, his treatment of the subject is typical of design studies. The model of designing being prior to making has remained an implicit feature of the field[2]. Even whilst acknowledging the material engagement throughout processes of design (in, for example, the practice of a couturier), there remains a commitment to prioritise the planning-based nature of the discipline. As I discuss below, this is symptomatic of a “design-centric” treatment of the relationship between thought and action. Crucially for my study, this approach inhibits the notion of what constitutes a valid subject of interest—it disregards the importance of tools, techniques and materials upon design processes. There has been, writes design researcher Theodora Vardouli, a ‘long tradition in which abstractions—models, descriptions, representations—of things have been viewed as a language proper of design, frequently coming to stand for the things themselves’ (2015, p.154; see, for example, Archer 1979). My determination to understand the techniques of material engagement throughout design processes is thus in accord with Vardouli’s suggestion for design researchers to supplement abstraction with materiality (2015, see p.154).

3.1.5. Horst Rittel on Plan Making

Unlike the subsequent move to understand design ‘problems’ and ‘solutions’ as co-evolutionary then, there has been little challenge within the discipline to the linear relationship between designing and making. Even in work like design researcher Horst Rittel’s *The Reasoning of Designers* (1987), which acknowledges the ‘disorderly’ nature of design problems (ibid., p.2), we still find a subscription to the definition of design as separate from its execution. In the following quote from Rittel, I suggest we see both further

[2] See Vardouli for a recent critique of this ‘design-centric’ attitude (2015, p.143-4).

evidence for the dominance of this assumption, but also the beginnings of a thread that we may follow into a valuable alternative.

> 'All designers intend to intervene into the expected course of events by premeditated action. All of them want to avoid mistakes through ignorance and spontaneity. *They want to think before they act*. Instead of immediately and directly manipulating their surroundings by trial and error until these assume the desired shape, designers want to think up a course of action thoroughly before they commit themselves to its execution. Designing is plan-making. Planners, engineers, architects, corporate managers, legislators, educators are (sometimes) designers. They are guided by the ambition to imagine a desirable state of the world, playing through alternative ways in which it might be accomplished, carefully tracing the consequences of contemplated actions. Design takes place in the world of imagination, where one invents and manipulates ideas and concepts instead of the real thing - in order to prepare the real intervention. They work with *models* as means of vicarious perception and manipulation. Sketches, cardboard models, diagrams and mathematical models, and the most flexible of them all, speech, serve as media to support the imagination.' (1987, p.1, emphases in original)

The designers of Rittel's definition *want to think before they act.* This is a restatement of the default approach Carl Knappett finds in archaeology (see 2.3.1), wherein thought is primary, and action secondary. For these designers, thought always precedes action. It is through challenges to this assumption, which promote instead an alternative, bi-directional understanding of the relationship between thought and action that I hope to build a productive theoretical basis for my work. The rest of this chapter will be devoted to this aim.

Before discussing such challenges, however, I suggest we can find a clue, hinting at the potential for such an exercise in the last few lines of Rittel's quote. Whilst the primacy of planning and internal cognition appears to underlie his position, we nonetheless see an acknowledgment that the plans of Rittel's designers are indeed *made.* They are made using things—drawings on paper, cardboard models, screen based diagrams—that do not just reside in the heads of the practitioners, but in their environment. In the next section of this chapter, I investigate the theory of extended mind and models of distributed cognition to suggest that the 'world of imagination' about which Rittel writes, might thus be understood to include features of the external environment. First, however, I look to an inspirational precursor to this argument.

3.2. Making Designs

Whilst design studies might be dominated by a dualism of thought and action, there is one notable exception that points the way to an alternative. Henrik Gedenryd's *How Designers Work: Making Sense of Authentic Cognitive Activity* provides a detailed critique of design studies and their relationship with cognitive theory (1998). Gedenryd demonstrates that the definitions like those found in Archer's early work are based upon a model of rational action that takes thinking and doing to be separate activities, wherein thought always precedes and determines action (ibid. see p.57).

3.2.1. Gedenryd's Folk Model of Cognition

Gedenryd identifies the links between this default view of production and a 'folk model of cognition' (ibid., p.37). The folk model presents an ordered sequence 'from perception to thinking to action, based on an imagined "flow" from input to output: Information enters through the senses and via perception goes into the mind. Then, a decision is made which transforms this information via the motor system into action, and this is regarded as "output"' (ibid.) (see Figure 3.1, after Gedenryd's Figure 1.9, ibid.).

Figure 3. 1 The folk model of cognition

That Gedenryd refers to this as a "folk model" is suggestive of how intuitive it feels. It is an 'example of a notion that is hard to rethink or disregard: How could it be different; how might it not be this way?' (ibid.). These are questions that Gedenryd offers valuable answers to. He provides a discussion of the historic basis for our most familiar understandings of cognition, and considers how these have influenced design theory. Gedenryd then demonstrates the flaws behind the folk model and its application, and suggests an alternative understanding of thought and action based upon the real experience of designers. As noted in a blog post by professor of design Chris Rust, that Gedenryd died not long after completing *How Designers Work* leaves us to 'wonder where he might have taken his knowledge if he had lived' (1998). It is only very occasionally, such as in Vardouli's recent discussion of making theory (2015) (see also, Knight and Vardouli 2015; El-Zanfaly 2015; Lim, Stolterman, and Tenenberg 2008; Brereton 2004; Gill, Sanders and Shim 2011), that the ideas suggested by Gedenryd's work have reemerged[3].

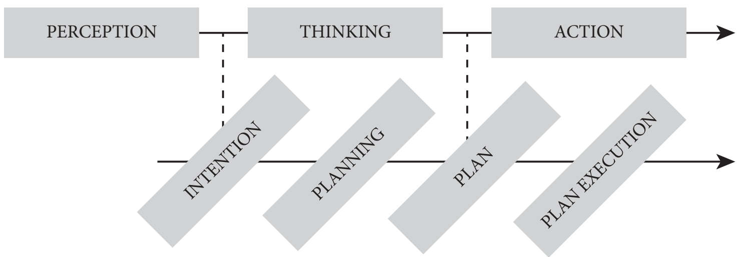
[3] I have found these ideas are more often ignored or, as in the case of design theorist Willemien Visser, dismissed on the basis that they do not 'establish an appropriate differentiation between human and artificial cognition' (2006, p.81).

Following the folk model of cognition, Gedenryd identifies another, similarly "common sense", triad (see Figure 3.2, after Gedenryd's Figure 1.10, 1998, p.38).

Figure 3. 2 The folk model of intention, planning and action

This second sequence is 'essentially a causal explanation of action'—of how action comes about and how it is controlled (ibid., p.37). Gedenryd describes it as a 'folk-psychological "theory" of action' (ibid.). The three-part sequence can be understood as a more focused instantiation of the more general folk model of cognition (ibid., p.38). It is similarly linear, but concentrates upon just the 'thinking' and 'action' parts of the first model. Figure 3.3 (after Gedenryd's Figure 1.11, ibid., p.39) places the two models on the same timeline, to help to illustrate this elaboration.

Figure 3. 3 The relationship between the folk model of cognition and intention, planning and action



As seen in Figure 3.2, the folk-psychological theory of action takes the creation of plans to be the defining feature of cognition. Intentions are the inputs that inform planning. Planning then controls action. The plan thus defines the relationship between thinking and doing—actions are understood to follow plans developed during "thought" (see 3.2.4 for other critiques of planning). As Gedenryd notes, in this refinement of the folk model of cognition, the 'origin of the intention is non-essential to the relation between thought and action', and can thus be left out (ibid., p.38). Both this feature of the theory of action, and the linear narrative illustrated in both Figures 3.1 and 3.2, leaves little space for the potential for action to influence perception or intention. I return to this failing below, when discussing the theory of extended mind, and in the next chapter, when I critique David Pye's writing along similar lines.

As we found in the example of Archer's PhD thesis, the ambition to define the requirements of a project in advance of design practice has since given way to a less linear understanding. There is now a recognition that problems and solutions co-evolve. On this subject, Gedenryd agrees that the 'conventional models' of early design science were flawed because they considered 'the problem as a given' (ibid., p.70). And he suggests that the underlying cause of this mistake was the adoption of rational, or "folk", models of action and cognition—'a large oversight that cannot be resolved by making minor adjustments to these models' (ibid.,).

For the purposes of my research, Gedenryd's most valuable contribution is this: although the commitments both of the individuals associated with early design methodology, and design studies more generally have shifted, Gedenryd does not believe that this underlying theory of cognition has been abandoned. Indeed, the chief contribution of *How Designers Work* is a fundamental challenge to what Gedenryd calls "intramental" accounts of cognition, wherein all thinking takes place in the head; as assumed by the folk theory of action. This does not, Gedenryd argues, correspond with observations of design practice. The main subject of *How Designers Work* can thus be summarized as a question: 'Why do designers work the way they do, when the traditional theories of cognition and design say that designers should be doing something quite different?' (p.101)

Gedenryd's work can be understood as an attempt to expose the flaws of these traditional models, by demonstrating their incompatibility with design practice, and then suggesting an alternative. The main flaw upon which Gedenryd focusses is the idea that all cognition takes place in the head. Even in light of revised assumptions about the definability of design problems, the orthodox view of design practice remains wedded to a foundation that neglects the role of the world in cognition.

Gedenryd counters this by analysing studies of design sketching (often taken from Donald Schön's studies of architectural sketching, see Schön 1983[4]) to demonstrate that sketches are not used only to render pre-existing ideas, but also to provide feedback throughout a design process. The practice of sketching helps to discover previously hidden qualities or characteristics of an emergent design. Gedenryd's analysis of thinking and drawing thus 'gives little justification for treating them as separate activities, but rather as two aspects of

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[4] See also Cross (2001, p.53) for a discussion of how Schon's work has provided a useful departure from 'design science' and its positivist doctrine.

one single activity. Thinking and sketching go on in parallel and mutually enable one another to move forward.' (1998, p.104)

Throughout *How Designers Work*, Henrik Gedenryd's primary interest is to use evidence from the practice of designers to challenge overtly mental accounts of human cognition. His study is intended to be as much a contribution to the field of cognitive science as it is to design theory. From my perspective, Gedenryd provides an invaluable source of inspiration from which to pursue a study of the role of techniques on design practice. Where I diverge from Gedenryd's path, however, is in the subject of our respective studies. Whilst we broadly share a theoretical foundation, it is what we use this foundation for that differs. Gedenryd develops a highly sophisticated account of design practice, and has ambitions for it to provide a more general theory of externalized cognition. He does this through third-hand analysis of accounts of design practice, combined with the deep theoretical examination summarized above. Later in this thesis, I employ the theory of extended mind as a basis from which to conduct first-hand studies of the influence of the techniques of material engagement of design processes. Although Gedenryd does discuss the production of three-dimensional prototypes, his is predominantly an analysis of the resultant objects, as external components of minds, rather than an investigation into the processes that went into their creation. Whilst he talks of the 'combination of soft lead pencil, drawing paper, and techniques such as thumbnails, which together enable a highly fluid and expressive way of working that computers are far from matching' (ibid., p.213), Gedenryd's analyses do not look in detail at the process of using such techniques. He instead develops more global ideas; such as a description of good "inquiring materials" being ones that, in common with many accounts of design practice, suits the current stage of the process, i.e. rough sketches early on to 'explore' (ibid., p.123) a problem, followed by more refined ones later on to test ideas through 'experimentation' (ibid., p.126). Gedenryd is thus satisfied to identify why such materials can be usefully employed throughout design practice, in order to make more general points about externalized cognition. My thesis, on the other hand, aims to "zoom-in" on these practices, in the same way that archaeologist Lambros Malafouris creates chrono-architectures of production techniques (see 2.6.12). And I do so with the primary motivation not of evidencing a theory of external mind: thanks to work like that of Gedenryd's, I feel assured to take this theoretical foundation as a basis. I am interested in looking in more detail at the features of "inquiring materials", and the ways they might influence processes of design.

Where, as architect Lars Spuybroek observes, 'tools are usually understood as mediators, as in-between instruments, as if the goal already exists, as if the end has already been reached'

(2011, p.300), I believe the foundation laid by Gedenryd (and those similarly minded scholars in other disciplines) enables me to study tools not just as inert instruments, but as influential components of cognitive systems. I propose that this reframing of action, as a part of thought, provides a useful grounding from which to consider the significance of techniques during processes of design. And it also begins to erode the dualism of designing and making instated by Alberti and implicit in much design theory.

3.2.2. The Theory of Extended Mind

Henrik Gedenryd seeks to advance extended understandings of cognition more generally than just in the field of design. In bringing together the practice of design with theories of extended cognition, however, he provides a rare example of their compatibility that benefits design theory as much as it does cognitive science. Following Gedenryd's lead, I now look into other work on the extended mind, so that I might draw on its insights into the role of action in thought.

In their influential paper, *The Extended Mind*, philosophers of mind Andy Clark and David Chalmers begin by asking, 'Where does the mind stop and the rest of the world begin?' (1998, p.7) As suggested by the paper's title, Clark and Chalmers' answer is to understand the mind not as limited by the bounds of the skull, skin, or body, but as a coupling of humans and their environment. Thinking thus takes place not only within the confines of human brains and bodies, but within a cognitive system that relies on two-way interactions between people and things. This is the central idea behind the theory of extended mind.

For Clark and Chalmers, examples of such cognitive systems can be found everywhere—in the rearrangement of Scrabble tiles, the use of pen and paper to solve math problems, and interactions with navigational instruments. Indeed, they regard the 'general paraphernalia of language, books, diagrams, and culture' all to operate as parts of extended minds (ibid., p.8). Under Clark and Chalmers' analysis of cognition, any aspect of a human's environment has the potential to become part of a human mind.

The ideas proposed in *The Extended Mind* are developed in more detail in Andy Clark's book *Being There: Putting Brain, Body, and World Back Together Again* (1997). This can be considered a classic text in the field. In the following extract, Clark draws on the example of assembling a jigsaw, to introduce the idea of 'action loops'.

> 'One (unlikely) way to tackle such a puzzle would be to look very hard at a piece and to try to determine by reason alone whether it will fit in a certain location. Our actual practice, however, exploits a mixed strategy in which we make a rough mental determination and then physically try out the piece to see if it will fit. We do

> not, in general, represent the detailed shape of a piece well enough to know for certain if it is going to fit in advance of such a physical manipulation. Moreover, we may physically rotate candidate pieces even before we try to fit them, so as to simplify even the more "mentalistic" task of roughly assessing potential fit. […] Completing a jigsaw puzzle thus involves an intricate and iterated dance in which "pure thought" leads to actions which in turn change or simplify the problems confronting "pure thought." This is probably the simplest kind of example of the phenomena known as action loops' (ibid., p.36)

A critical foundation for both Clark's theory, and my later analyses of tool use, is a bi-directional understanding of thought and action. The action loops used when assembling a jigsaw demonstrate this back and forth character. The theory of extended mind promotes the idea that actions are performed not just to advance toward a goal, but also to help work things out. Rather than seeing tool use as a means by which to transcribe predetermined forms onto paper, screens, or three-dimensional materials, an extended approach to cognition recognizes that there are occasions when tools are used to find out what these forms should be. Cognitive scientists David Kirsh and Paul Maglio here provide a useful distinction, by describing two kinds of action: pragmatic action and epistemic action (Kirsh and Maglio 1994) (see 4.2 for a longer discussion of this idea). The former refers to actions intended 'to bring one physically closer to a goal' (ibid., p.513), and the latter sees actions 'performed to uncover information that is hidden or hard to compute mentally' (ibid.). For example, rearranging Scrabble tiles or jigsaw pieces can be considered epistemic action in that the tiles are moved to help reveal how they might be used in the game. When parts of the world are used in this way—so that, 'were it done in the head, we would have no hesitation in recognizing [it] as part of the cognitive process'—then Clark and Chalmers believe the things used should be recognized as the components of minds. 'In a very real sense,' they write, 'the re-arrangement of [Scrabble] tiles on the tray is not part of action; it is part of thought' (1998, p.10).

Importantly for my study, the theory of extended mind proposes that wherever we find such epistemic action, a 'spread of epistemic credit' should occur across the non-human components of minds (ibid., p.8). The studies of technique discussed throughout Chapters 5 and 6 are my attempt to bestow tools with epistemic credit, and an exploration of how we can better understand design tools and techniques in these terms.

For archaeologists, the theory of extended mind has offered a new methodological foundation from which to consider the relationship between thought and things. In the traditions of the discipline, as Carl Knappett describes, there was a 'Cartesian' tendency to treat the mind as a 'domain separate from the body and the world' (2005, p.35). Material remains were studied in an effort to understand behaviour, which could be interpreted as the expression of antecedent thoughts in the minds of people. Although this might remain ‘the implicit model behind most archaeological accounts of prehistoric cognition’ (Malafouris 2004 p.54), Knappett is part of recent efforts in archaeology to move beyond this separation of mind and world (see also DeMarrais, Gosden and Renrew 2004; Renfrew 2010; Knappett and Malafouris 2008).

Knappett is critical of the way this understanding portrays the body as a passive receptor of stimuli from the environment and the brain as a ‘kind of central processing unit’, which interprets sensory information and formulates responses to be ‘conveyed to the body and enacted in the external environment’ (2005, p.35). By drawing on the insight of extended mind theory and associated work, Knappett attempts to develop a distributed, situated and embodied approach to cognition and material culture. Central to this effort is the idea that actions are not always performed to realise antecedent representations in the brains of people, or even to move them towards a goal. By demonstrating the possibility that some actions are a part of thought, Knappett aims to undermine any dualism of mind and world.

3.2.3. Material Engagement Theory

In his book, *How Things Shape Mind* (2013), Lambros Malafouris presents the same criticisms of internalist accounts of cognition that we find in the above literature. His position towards archaeological theory and practice is similar to that of Carl Knappett. In short, Malafouris believes that his discipline’s assumptions about the relationship between cognition and action need to be redressed. Malafouris sketches out the failings of these assumptions in a familiar fashion—they are ‘dualist’, ‘internalist’, ‘neurocentric’ (ibid., p.3), and ‘tend to leave material culture outside the cognitive equation’ (ibid., p.10). In *How Things Shape Mind,* Malafouris develops his ‘Material Engagement Theory’ as a way beyond these shortcomings. It is intended to offer ‘a new relational ontological foundation’ (ibid., p.35).

Material Engagement Theory is founded on an extended understanding of mind. The “relational ontology” connects people and things according to the idea that they may be understood as cognitive systems. The boundary of the “mind” is, therefore, one of Malafouris’ recurring themes. For archaeological studies, the implications and appeal of extended mind theory is easy to understand. In a discipline concerned with studying material remains, if those remains may be reconceived as the components of cognitive systems, it certainly advances their epistemological potential. Rather than being the results of cognitive processes, artefacts can be understood as parts of those processes. For Malafouris’ interests in the prehistory of mind, and the evolution of human intelligence, this gives reason to be enthusiastic. There is no prehistoric brain tissue to study, and no early hominins to put in an MRI scanner. Bits of material culture are all that is left.

In a novel interpretation of ancient cave engravings, Malafouris neatly demonstrates the potential of the material engagement perspective. Instead of understanding carving as a means to externalise representations of an image held inside the mind of a prehistoric carver, Malafouris argues that the process of engraving might have been a 'technique through which a new consciousness of the physical world was attained' (ibid., p.202). The depictions, according to Malafouris, offered people a 'kind of perception of the world that was not previously available' (Ibid., p.203). In this way, the carvings are what Clark and Chalmers would consider a part of thought, rather than merely the results of action. They are components of minds, and can be studied as such.

Although developed from an archaeological perspective, I've found Malafouris' material engagement theory to offer a valuable insight into the potential application of work on extended mind. I find two of his contributions particularly valuable: the description and study of the 'chrono-architecture' of techniques (as discussed in 2.6.12), and his evaluation of the state-of-the-art in extended mind theory. It is this latter contribution that I explore here.

In *The Extended Mind*, Clark and Chalmers introduce the idea of "active externalism". For Malafouris, this represents a crucial aspect of the theory. It is important to recognise, explains Malafouris, that the theory of extended mind had a precedent in "externalism". This position, now widely-acknowledged, takes the view that cognitive *content* can be externalised. In a diary, for example, proponents of externalism would see an externalisation of our memory. Where Clark and Chalmers' active externalism developed this idea was to understand not just static *content* as externalised, but also dynamic cognitive *processes.* Malafouris writes:

> 'Whereas mainstream externalism (or the idea of external symbolic storage) implies externalization of cognitive content, active externalism implies externalization of cognitive states and processes. For active externalism, marks made with a pen on paper are not an ongoing external record of the contents of mental states; they are an extension of those states. Cognition and action arise together, dialectically forming each other. There is a huge ontological distance between a mind able to externalize its contents to material structures and a mind whose states and processes aren't limited by the skin' (ibid., p.74)

In Gedenryd's example of designerly drawing, this is the '[t]hinking and sketching' that 'go on in parallel and mutually enable one another to move forward' (1998, p.104). We do not draw just to externalise ideas that may then be evaluated. The process of sketching is a process of thought. As Malafouris describes, it is important to fully appreciate this implication of active externalism. It is very much distinguished from the more mundane, less controversial idea of externalised content. And it asks us to dispense of any lingering notion of discrete internal and external mental processes (see also Aydin 2015). 'In a very important sense,' writes Malafouris, 'from the perspective of material engagement, *cognition has no location*. The active mind cannot be contained. Cognition is not a "within" property; it is a "between" property' (2013, p.85, emphasis in original). This idea of cognition being "between" the features of a cognitive system is an idea I return to in Chapter 5, when I present one of the features of epistemic character—the questions posed by a technique (5.1).

3.2.4. Distributing Cognition and Planning

I have outlined the theory of extended mind here because I believe it offers a readily understood introduction to the theoretical foundation underlying this project. It should be noted, however, that Clark and Chalmers were not, and are not, lone voices in calling for this view of cognition. Examples of a similarly distributed approach stretch back before Clark and Chalmers' theorizing of the extended mind (see, for example, Suchman 1987; Hutchins 1995; and Pickering 1995). And in more recent years, such examples can be found with ever-increasing frequency (see, for example, Ingold 2013, Malafouris 2013, Bennett 2009). I've relied on the theory of extended mind here not to suggest that it is unique but because, in and among the different terminologies applied by various authors, it offers a concise explication of this general, cross-disciplinary tendency toward distributed models of cognition[5]. In *The Extended* Mind, Clark and Chalmers are themselves alert to the similarities between their own work and that of others; they draw on other studies to stress that their work is much more than an exercise in redefining the word "mind": '[S]eeing cognition as extended is not merely making a terminological decision,' but proposing a way of thinking about cognition that 'makes a significant difference to the methodology of scientific investigation' (1998, p.10). They use the work of others to demonstrate that conceiving the mind as a system that includes features of the external environment allows interactions with that environment to be subjected to novel analyses.

[5] See also Sutton (2006), for a discussion of the relationship between the theories of distributed cognition and extended mind.

A classic text in the field of distributed cognition is Edwin Hutchins' book *Cognition in The Wild* (1995). As an anthropologist, cognitive scientist, and open-ocean racing sailor, Hutchins develops an account of cognition in the context of nautical navigation. The "wild" aspect of his work is that this is a resolutely "real-life" study of cognition, not one conducted through a series of laboratory tests. Through time spent aboard naval vessels, Hutchins develops a description of how sailors navigate that focusses not just on individual minds, but large groups of people and an environment filled with instrumentation. Hutchins' concern is to describe how this system of people and things is not guided by a detailed plan held centrally: the knowledge required to solve the problem of navigation is instead spread across each component of the cognitive system (ibid., p.199). In Clark and Chambers' terminology, it could be said that Hutchins spreads epistemic credit across this system of people and things.

This criticism of centralized planning and control is typical of distributed or extended approaches to cognition. It is a theme taken up by Clark in *Being There*, where he describes the situation we have seen identified in Gedenryd's "folk" theories as a 'classical disembodied vision of planning' (1997, p.63). This 'imagines, in effect, that complex sequences of actions are determined by an internalized version of [a] set of instructions' (ibid.). It is to assume a linear, one-way path from intention to planning to action, where we adopt the idea of 'plan-as-program' (ibid., p.63) and infer that 'there exists layer upon layer of increasingly minute plans exhaustively controlling our every move' (Costall and Leudar 1996b, p.169). Of course, no description of planning, however (ir)rational, would suggest that plans are infallible. It is uncontroversial to admit that plans often go awry. But what Clark, Hutchins and the following examples propose is to fundamentally rethink plans as 1) non-internalised, and 2) not entirely specified.

In Hutchins' study of navigation, for example, the idea that plans can be centralised, internalised or entirely specified is discredited by the observation that no member of the crew, even the captain, knows in detail every action that must contribute to a successfully steered course. Instead, each person and instrument is doing its own small bit, responding to what Clark calls 'local environmental alterations' (1997, p.77) with an appropriate action. It is the collective force of people responding to these partial commands, which in turn create the situations for other subsequent actions, that leads, step-by-step, to successful navigation. That all these human actions are performed using tools and instruments that themselves structure and support cognition, in an environment organised to 'reduce the complexity of problem solving' (ibid.), leads Hutchins to claim that cognition in the wild is fundamentally distributed.

Whilst Hutchins' discussion focusses on a situation that is collaborative—navigation is a joint enterprise with multiple human actors—other, similarly themed, criticisms of the plan-as-program understanding also demonstrate its flaws at the individual level. One such (likewise water-based) example can be found in anthropologist Lucy Suchman's description of canoeing down a set of rapids (1987, p.52). Whilst Suchman acknowledges that a canoeist at the top of the rapids would develop a loose plan of how to negotiate the hazards in front of them; by, for example, aiming to get as far to the left as possible, or using large rocks as waymarks for certain turns, it does not follow that it is this plan that controls the action. '[T]he purpose of the plan in this case', writes Suchman, 'is not to get your canoe through the rapids, but rather to orient you in such a way that you can obtain the best possible position from which to use those embodied skills on which, in the final analysis, your success depends.' (ibid.) This canoe analogy is taken from Suchman's book *Plans and Situated Actions*, in which she develops and promotes the idea of "situated action" in order to capture the emergent nature of action, as it is created through 'moment-by-moment interactions' between people and their environment (ibid., p.179).

Whilst Suchman thus recognises that plans do play a role, she claims their execution is always situated in changeable contexts and requires intelligent improvisation[6]. The situated action approach proposes a rebalancing of the dominance of planning and plans, by promoting, in Clark's words, the 'complex interplay between the plan and the supporting environment' (1997, p.63).

To return to the subject of instructional literature discussed in the previous chapter (2.6.5), we here find an analogy to the idea of plans as loose resources, rather than programs for action. The sequences of action specified by instructional texts are kinds of plans. They are not, however, highly specified plans that make explicit every feature of practice. As philosophers Costall and Leudar observe in a discussion of instructional texts on skiing and wallpapering (1996b), such guides do not specify every detail, but they specify enough to be useful[7].

Anthropologists Charles Keller and Janet Keller, here provide a useful term—"umbrella plan" (1996) (see 5.3.1). An umbrella plan is created before work begins and 'integrates the

[6] On this point, Suchman (1987, p.200) for an interesting discussion of David Turnbull's work on Gothic building, and how it is the under specification of plans that makes them work.

[7] On this subject, philosopher Beth Preston presents and interesting discussion of cooking by following recipes (2013, see p.39-43), as does philosopher Andrew Harrison (1978, see p.71-2).

overarching formal goal with an outline of a rough procedural sequence for attainment […]. Enacting the initial steps and evaluating the material results of that action allow an individual to revise and elaborate the umbrella plan and further specify steps for attaining the increasingly detailed representation of the end product' (ibid., p.127). In the context of their study—a traditional blacksmith's workshop—Keller and Keller suggest that the concept of an umbrella plan, which is open to revision throughout production, helps to move 'beyond analyses that would focus exclusively on either mind or matter to see their integration and mutually constitutive contributions to planning and production' (ibid., p.23). This allows Keller and Keller to appreciate the productive influence not just of ideas internal to the smith, but also recognise the effect of their tools, techniques, templates, workshop arrangement, and the behaviour of the iron itself.

It seems obvious that this degree of material engagement would be fundamental to a craft as physical blacksmithing. Interestingly, however, Keller and Keller do not aim only to identify the nature of a smith's work; they are also eager to extrapolate from the specifics of their chosen context to develop a more general account of human accomplishment. And it is on this theme, of what might be called "ubiquitous material engagement", that I end this section with. To do so, I turn to another account of the role of the world in human performance—sociologist of science Andrew Pickering's characterisation of scientific practice. Even though it might seem far removed from the apparently ancient techniques of blacksmithing, the techno-scientific examples Pickering draws upon tell the same tale of moment-by-moment interaction with the world.

In *The Mangle of Practice: Time, Agency and Science*, Pickering argues that there is a popular misconception of scientists as 'disembodied intellects making knowledge in a field of facts and observations' (1995, p.6). This casts the practice of science as somehow removed from the world of materials, aiming to produce knowledge chiefly through models and representations. Pickering's aim is to rebalance this understanding, by emphasising the material conditions of practical science. Scientists, Pickering reminds us, conduct experiments in the real world. They encounter the same material resistances that everyone else does—as we do things to the world, it does things back and, very often, this response is not the one that was either intended or expected. Things go wrong, models and machines don't work, goals are often revised throughout. Far from a predominantly conceptual activity, Pickering therefore suggests we think of scientific practice as a 'dance of agency', between human and non-human actors (ibid., p.21)[8]. In this dance, scientists shift between

[8] I return to the notion of agency in more detail in section 5.3.

periods of activity and passivity, between doing things—modifying a machine, mixing a new compound, introducing a new variable—and then monitoring the results. There is a back and forth between themselves and an emergent result.

According to his interest in Science and Technology Studies (STS), Pickering draws examples from experimental particle physics and the early days of computer numerically controlled (CNC) machine tools. In each case study, he is interested in demonstrating how the metaphorical dance of agency plays out, as people try, and often fail, to get machines to perform as they would like. For Pickering, material agency is 'temporally emergent in practice' (ibid., p.14)—it is what the world "does back" in response to human agency. Importantly, despite popular conceptions of science that might champion representation and predication, Pickering argues that '[t]he contours of material agency are never decisively known in advance, scientists continually have to explore them in their work, problems always arise and have to be solved in the development of […] new machines' (ibid.). What might be considered the umbrella plans of scientists and technologists are thus respondent to change in the same manner as Keller and Keller's blacksmiths. Just like when working with heterogeneous molten iron, Pickering stresses that the apparently unknowable properties of the material world also affect techno-scientific practice. Pickering calls this interaction a 'dialectic of resistance and accommodation' (ibid., p.39), where resistances are a block on the path towards a goal (caused by emergent material agency), and accommodations are ways of incorporating this new reality into a revised approach, made in response to the resistance. It is in this way that materials and humans become partners in Pickering's dance[9].

The notion of material agency leads us to the next section, where I wish to discuss what could be considered the philosophical foundation to many of the subjects discussed above.

To first return briefly to the topic of plan-making (the thread that lead us out of Rittel's description of design practice), however, I hope the discussion of extended and distributed models of cognition has helped to illuminate the following claim: whilst it is reasonable to understand design as a plan-making enterprise, it is important to recognise that those plans must be *made*. And they are not made in advance of their material realisation, but "along-the-way", through episodes of material engagement.

[9] Further to Pickering's work, an interesting perspective on the similarities between scientific and design practice can be found in Glanville (1999, specifically p.86-91)

3.3. Two Philosophies of Design

"How are things made?" This is a question that might seem to prompt the clarification, "how is *what* made?" Whilst we are accustomed to enquiring about the specific production processes of particular objects: "how is a brick made?"; "how is a light bulb made?"; "how is a cricket bat made?", to consider the question at a more general level, "How are *things* made?", is to expose the kind of widely-held assumptions about the processes of designing and making (and thought and action more generally) described above.

As found in Alberti's account of architectural practice, the orthodox answer to the question could be summarised as follows:

> *Things are made according to a design. An intention exists in advance of production, in isolation from its realisation in material. During processes of designing and making, pre-conceived forms are imposed upon the material world. A practitioner thus makes something by starting with an idea of what they want to achieve, and then manipulating materials until they take on this form.* (see Ingold 2010 for similar formulations)

Having already discussed criticisms of the linear relationship between thought and action that underlies this statement (a point to which I return in the following chapter), I now wish to consider what might be an alternative answer. For disciplines interested in people's relationship with the material world, this kind of investigation is already a key concern. Anthropology, archaeology and philosophy thus provide me with useful guides. As the assumptions upon which the orthodox view is based have come under increasing challenge in these disciplines, new approaches to the question of 'How are things made?' have been developed (see, for example, Malafouris 2013; Ingold 2013). Because the foundation of this default approach runs deep through Western thought, it is typical for these new approaches to first retrace this idea back to a fundamental dualism between mind and matter (see, for example Knappett 2005; Preston 2013; Conneller 2011). What they find is a separation between the world of ideas (mind) and the world of materials (matter). In essence, the revised approaches to the question of 'How are things made?' share a common theme—which we have already found in work on the extended mind—to reunite and rebalance this relationship between people and the world.

3.3.1. Aristotle and Hylomorphism

A recurring theme in discussions of the philosophy of designing and making is to trace the division between *form* (the idea, or design, that exists in advance of its material realisation) and *matter* back to Aristotle (see, for example, Protevi 2001; Gedenryd 1998; Ingold 2013; De Landa 2001; El-Zanfaly 2015). In *A Philosophy of Material Culture* (2013), Beth Preston provides a detailed account of Aristotle's contribution to this idea. Summarising his text in *Metaphysics*, Preston describes how Aristotle's production process 'starts with a specification of the thing to be produced (the form in the mind of the producer)', after which 'the ensuing deliberation or thinking concerns the specification of the steps by which this form may be realized in matter. So, at the end of the thinking process, the producer has in her mind a mental design for the product' (ibid., p.18). Preston then goes on to observe the division Aristotle thus creates between designing and making;

> 'Aristotle suggests that this mental design is finished prior to the production proper, the actual construction. So, for Aristotle, there are two clearly demarcated phases in the overall production process—an antecedent design phase and a subsequent construction phase. Moreover, since all of the thinking is relegated to the design phase, the construction phase must be a matter of unintelligent execution of the step-by-step instructions. Thus, for Aristotle, the real interest of production lies in the mental process of design, not the actual construction process.' (ibid., p.18)

It is easy to see, from Preston's summary of Aristotle's work on production, why he has been co-opted as the archenemy of those proposing non-dualist interpretations of designing and making. His concept, sometimes referred to by its technical term—hylomorphism (owing to its bringing together of *hyle*, or matter, and *morphe*, or form)—is often understood to be at the root of divisions between thought and action.

In *Political Physics* (2001), John Protevi offers a useful account of the philosophy hylomorphism. Drawing on the work of fellow philosophers Deleuze and Guattari (1988) (themselves indebted to Gilbert Simondon - see Bennett 2009, p.56), Protevi contrasts the behaviour of the "architect" with that of the "artisan", to illustrate the hylomorphic model with reference to material engagement (ibid. p.8). The architect here becomes the archetype of hylomorphism, defiantly refusing to 'surrender' to the inherent properties, or resistances, of materials. Forever seeking to 'command' materials from afar, the architect treats matter as an inert substrate for a preordained form (ibid.). The artisan, on the other hand, who is (following Deleuze and Guattari's example) a woodworker, does surrender to materials. The artisan is receptive to the self-ordering potential of timber and his or her forms are thus developed according to these 'suggested potentials of the matter rather than being dreamed up and then imposed on a passive matter' (ibid.).

It should be noted that the "architect" of Protevi's discussion is only 'an ideal figure of hylomorphism' (ibid, footnote 23). Protevi uses the metaphor of architect vs. artisan as a means to contrast two modes of material engagement, which might be considered the opposite ends of a spectrum, rather than discrete categories. Protevi thus points out that the observation that 'a real person with the professional title "architect" is aware of material limitations to the imposition of form is no escape from hylomorphism' (ibid,). The "ideal architect" is intended as a useful illustration of a way of thinking. It serves, for example, to illustrate the political angle to Protevi's work, which sees him build out from the specifics of material engagement, towards broader concerns—he sees the hylomorphic idea 'that a simple unchanging commanding origin is responsible for change in others [as] one of the fundamental philosophical issues of the West' (ibid., p.8). Promoting instead the artisanal ideal of recognising and coaxing forth the inherent properties of materials, argues Protevi, might offer a valuable shift in behaviour.

Protevi's contrast of the architect and artisan, and their alternative approaches to material engagement, is the same idea (also borrowed from Deleuze and Guattari) that we find in an essay by Manuel De Landa. De Landa describes two 'different philosophies of design, or what amounts to the same thing, two theories for the *genesis of form*' (2001, p.132). The first of these theories aligns to Protevi's architectural approach: it is the one underlying Alberti's separation of a design and its execution, and the derivatives that have followed since. In this theory, 'one thinks of form or design as primarily conceptual or cerebral, something to be generated as a pure thought in isolation from the messy world of matter and energy. Once conceived, a design can be given physical form by simply imposing it on a material substratum, which is taken to be homogenous, obedient and receptive to the wishes of the designer.' (ibid.) 'The opposite stance', De Landa describes, 'would be represented by a philosophy of design in which materials are not inert receptacles for a cerebral form imposed from the outside, but active participants in the genesis of form. This implies the existence of heterogeneous materials, with variable properties and idiosyncrasies which the designer must respect and make an integral part of a design process' (ibid.).

De Landa presents these two philosophies of design alongside a discussion of materials. The first, he suggests, is encouraged, and in many ways satisfied, by a modern material like steel. Drawing on the work of materials scientist James E. Gordon, De Landa suggests that the highly uniform, predictable behaviour of steel makes it ideally suited to being manipulated following a hylomorphism-inspired approach. Indeed, Gordon suggests that the widespread adoption of steel has as much to do with this predictability, as it does steel's technical properties (Gordon 1988, see p.135). The accumulated experience of working with the material has enabled the design of many components (Gordon cites the example of gear wheels) to be routinized, as designers can be assured that the steel parts will behave exactly as expected.

In contrast to the obedience of steel, De Landa presents the heterogeneous iron of an historic blacksmith as a typically artisanal material. Depending on the fluctuating availability of material at their local foundry, the properties of the smith's iron would vary markedly, requiring that they be sensitive to its individual characteristics, and sympathetically coax it into shape. De Landa considers the successive heating, hammering, annealing and quenching of the artisan, in this way, to be "non-routinisable"; they must always be alert to the emergent nature of their work and develop forms accordingly.

In comparing the practiced, dexterous techniques of a blacksmith with modern steel fabrication, De Landa risks equating the contrast between the hylomorphic model and his alternative proposition with a distinction between "craft" and "industry". It might seem, on the strength of these examples, that the two "philosophies of design", or "theories of the genesis of form", introduced by De Landa can be understood chronologically—on a timeline running from the embodied knowledge of traditional smiths, up to the standardised and computer-modelled creations of modern engineering. We might thus interpret an increasing command over materials and the associated philosophy of hylomorphism as an inevitable consequence of industrialisation. Indeed, in his analysis of steel and its effect upon design processes, James Gordon writes that it is 'archetypically, the material of big business—of large factories, railroads and so on' (ibid.). As material science becomes more and more adept at controlling the properties and behaviours of materials, industrialised production seems to resemble ever more closely the model of ideal forms being imposed upon inert, docile and receptive matter[10]. Before subscribing to this understanding, however, it will be useful to investigate the idea of craft, and the validity of contrasting it with a thing called industry.

3.3.2. Craft and The Control of Materials

The 'fantasy of control over materiality', writes Glenn Adamson, 'is one of the signature elements of modernity' (2013, p.89). In the context of contemporary techniques, this fantasy is perhaps most clearly expressed in the efforts to develop digital materials. As computer scientist Neil Gershenfeld describes, the current ambition is to develop components just a few nanometers long, which can be programmed to self-assemble and disassemble with one another using Lego-like alignment mechanisms (2012). This is quite different to existing digitally-controlled fabrication techniques, which control the motion of tools that manipulate

[10] Elsewhere, however, Gordon reminds us that, whilst our idealised models of materials treats them as static and unchanging, this is only ever an abstraction of reality. See, in particular, his discussion of 'creep', which, despite the contrary assumptions of elementary Hookean elasticity, sees substances move over time under a constant load (1978, p.145-8).

analogue materials. Our current digital techniques are limited by the properties of the material being worked, the accumulation of errors throughout processes, and the size of the machine. The individual building blocks[11] of digital materials, however, would snap together without error; define their own spacing and thus grow to any size outwith a machine bed; be designed to have electrical and magnetic properties; and, once the assemblies are no longer required, they could be broken back down to a bag of bits. Gershenfeld expects digital materials to one day be used to make things from tiny '3D-integrated circuits', up to 'larger structures, such as aircraft components and even whole aircraft that will be lighter, stronger, and more capable than today's planes—think a jumbo jet that can flap its wings' (ibid., p.52). The ultimate aspiration is to revolutionise all manufacturing processes, to the degree that things are no longer moulded, machined or forged, but all assembled from a set of cell-like parts. In the promise of digital materials then, we find a recurring theme in technology, of technical developments inspiring radical new visions of human production.

In *The Invention of Craft*, Adamson describes how the newly-available materials of papier mâché, rubber and cast iron appeared to Victorians to 'short-circuit traditional understandings of making', allowing technique to operate independently of the human hand (2013, p.89). The remarkable plasticity of these materials—their capacity to be moulded into complex shapes—differentiated them from the materials of old. In the face of new technical possibilities, existing practices began to be regarded as an entirely different kind of production. It is in this context, argues Adamson, that "craft" was invented.

Advances in the techniques for casting iron had a particularly dramatic effect, leading 'immediately to the idea of the blacksmith as a figure rooted in the past, or at best the pastoral scenery of the countryside' (ibid., p.79). Well before the modern steel of De Landa's comparison then, it was the innovations of coke (as a fuel for the smelting furnace) and the steam engine (to continually pump air through the furnace)[12] that made possible the foundry's development, and began to erode the smith's monopoly on the business of metalwork.

During this time of industrialisation, Adamson argues that the opposition of craft and industry was also engendered by inventors and innovators seeking protection from newly devised patent systems. The likes of Wedgwood, Babbage and Edison were eager to distinguish themselves from the 'echelon of artisans', and did so by defining invention in purely intellectual terms—'a matter of the mind alone that was not guided by human hands'

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[11] For an interesting critique of the metaphor of "building blocks" see Ingold (2013b).
[12] See p.76 of Adamson (2013)

(ibid., p.74). Creativity was thus promoted in terms cerebral novelty, and the technical expertise of craftspeople was characterised as a matter of mere mechanical execution[13]. Here we find, perhaps surprisingly, that a dualism of mind and matter, and the hylomorphic model of production, played their part in the genesis of popular ideas about "craft"[14].

In truth of course, as Adamson documents throughout his book, there is more to making than mechanical execution. Technicians, even those working with apparently pre-determined techniques, must still negotiate the resistances of their tools and materials. No doubt the work going on at Gershenfeld's *Centre for Bits and Atoms* in MIT is highly experimental, requiring the same dance of agency found in Pickering's other techno-scientific settings. Looking to the history of digital fabrication, this point is demonstrated in David Noble's illuminating account of the introduction of computer-numerically-controlled (CNC) machine tools to a General Electric (GE) production plant (1986; see also, Pickering 1995, p.157-176). On GE's factory floor, the expected narratives about deskilling and rises in efficiency did not apply. It was only the improvisatory practice of machinists that eventually enabled GE's CNC techniques to be successfully implemented. Although such feats of technical expertise are "hidden" by the time artefacts roll off a production line, both Noble and Adamson show us that, behind-the-scenes, "craft" and "industry" are inextricably linked.

3.3.3. How Things are Made

By dividing the architectural and the artisanal modes of production, we introduce a dualism. In light of much of the above literature's efforts to discredit the dualisms of mind/matter, thought/action, or designing/making, this seems an odd strategy. And, according to our examination of the origin of this distinction, nor does it appear particularly substantive. The concept of craft was created in response to industry, but the two fields of production were always, and remain, co-dependent[15]. To return to our prototypical architect, we have read

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[13] Tim Ingold and Elizabeth Hallam have presented an interesting criticism to this association of creativity with novelty. They challenge 'the polarity between novelty and convention, or between the innovative dynamic of the present and the traditionalism of the past, that has long formed such a powerful undercurrent to the discourses of modernity' (2006, p.2). Their strategy is to focus on the creativity of improvisation, rather than the novelty of creativity. As Beth Preston suggests similarly, 'improvisation displays a kind of creativity distributed throughout the action itself' (2013, p.91).

[14] A defining characteristic of "craft", for example, is identified by sociologist Richard Sennett as the capacity to solve problems as one goes (2008, p.19-20). Adamson shows that innovators were cast in opposition to this, as those working in the idealised model of Alberti: thinking, planning and solving *before* they acted.

[15] As seen in David Pye's discussion of the reliance of factory production on the workmanship of risk (1968, p.23), and David Knott's discussion of contemporary amateur craft practice (2015)

about how Alberti's actual building practice failed to live up to his representational aspirations. As Protevi cautions us then, these two philosophies of design should only be understood as the poles of a spectrum.

In an essay that helpfully applies the hylomorphic model in the context of artisanal production, philosopher Vilém Flusser leaves us between these poles, in the middle ground. Using the example of a wooden table, Flusser explains that, following hylomorphism, we can take the actual material table (which we could eat a meal around) to be a transient realisation of an eternal table form (which can be held forever in our imaginations) (1999, p.24). Whilst the table itself will one day rot or be burned for fuel, the design for that table, its form, stands apart from the material world and is ever-lasting. Like those examples discussed above, Flusser traces the origins of this idea back to its Greek root (ibid., p.22). To make a table according to this philosophy is to impose an eternal form onto materials. 'This illustrates', Flusser writes, 'what carpenters do: They take the form of a table (the idea of a table) and impose it upon an amorphous piece of wood. The tragedy here is that in so doing they not only in-form the wood (impose the table form on it) but also deform the idea of the table (distort it in the wood). The tragedy is therefore that it is impossible to make an ideal table' (ibid., p.24). When up against the recalcitrant nature of timber, the carpenter's hopes of controlling materials remain a fantasy[16].

I suggest the best way to get over such a tragedy is to recognise that it is just the way things are. This is what opponents of the hylomorphic model are advocating. Although it is a caricatured account, the dualism of architect and artisan serves the purpose of exposing assumptions that might otherwise go unrecognised. It forces us to reconsider the folk theory of action described by Gedenryd, and challenge the dominant theory of production that disregards the role of material engagement. This more emergent[17] understanding of designing and making suggests an enhanced appreciation for the *making of designs*. And, crucially for my study, we find an interactive relationship between doing and thinking.

[16] As David Pye observes, '[t]he only considerable technical limitations on design are imposed by our ineptitude at processing material [...]. It seems unlikely that this deficiency will ever be made good' (1978, p.44)

[17] I use "emergent" here in two senses: firstly, it captures the emergent nature of form throughout productive processes, a quality promoted in non-hylomorphic models. Second, I hope it speaks of the nascent, multidisciplinary and increasingly widespread attempts at shifting towards alternative theoretical models of making as an engagement with materials.

3.4. Summary

To summarise the influence of the above literature on my research, it provides a theoretical grounding that:

- Accepts that design is a plan-making discipline, but emphasises that those plans must be made through techniques.
- Understands cognition to be spread between the various parts of a technique (the practitioner, tool and material), and therefore ascribes epistemic credit to each part.

This chapter has covered ground from a range of disciplines, all in an effort to illuminate the distinction between designing and making. In Alberti's foundational text, we found that the practical division of these two elements of production first took root in the architecture of the Renaissance. Through Bruce Archer and Horst Rittel, we saw how this division has continued to be an implicit assumption of more recent design theory.

With Henrik Gedenryd's work came an alternative understanding, that sought to reconcile the dualism of designing and making or, more generally, thought and action. This lead us away from design-focussed literature, into questioning the limits of "mind". Here I hope to have shown that the excursion into the idea of "extended mind" and "distributed cognition" provides us with a useful foundation from which to re-evaluate the relationship of designing and making. A key contribution of this section was the idea that, even if we subscribe to the model of design as a plan-making discipline, the plans still need to be *made* with something. Another extra-disciplinary tangent followed, as we traced the philosophical underpinnings of Alberti's theory, and contrasted them with an alternative philosophy of material engagement.

I conclude with two quoted passages, in order to reaffirm what I believe is the advantage of the theoretical grounding developed in this chapter. Familiarising myself with the literature discussed above has had a significant impact upon how I interpret any writing on the subject of designing and making. Take, for example, design theorist Per Galle's (admittedly propositional) definition of design: '[c]reatively proposing an idea, so as to enable yourself or others to make an artefact according to the idea' (2011, p.93). Once sensitised to the theory of extended mind and criticisms of hylomorphism, I've found such a casual delineation of the realms of thinking and making to be quite jarring. And it often strikes me that work like Per Galle's could be radically (and I would suggest beneficially) reconceived with reference to ideas like those I've been exploring. In the following two quoted passages then, I contrast “the problem” of design theory’s internalist position, with “the solution” of Tim Ingold’s materially-engaged understanding.

The first passage is from the same paper as Per Galle’s definition…

> ‘[I]t seems to me that, to obtain a sufficiently deep understanding for coming up with a full-fledged foundational design theory, we need to address the vexed questions that arise from the simple fact […] that at the time a given artifact was designed, it did not exist. For example, according to a widely accepted understanding of properties, they are always properties of some existing entity. From this perspective, as long as the artifact did not exist, it could not have had any properties. Thus, at the time of its design, the artefact could not have had the particular property of serving its purpose. How then, could the designer know (or be confident) at that time that the artifact would eventually serve its purpose? Prediction rather than predication of properties appears to be involved, but what exactly does that mean, and what, if anything, makes it reliable? How, indeed, is design possible—thrusting forward, as it does, into an empty space of non-existence?’ (2011, p.94)

… and from Ingold’s book, *Making*…

> ‘Artists, architects, composers and writers are likewise bent upon capturing the insights of an imagination always inclined to shoot off into the distance, and on bringing them back into the immediacy of material engagement. Like hunters, they too are dream catchers. Human endeavours, it seems, are forever poised between catching dreams and coaxing materials. In this tension, between the pull of hopes and dreams and the drag of material constraint, and not in any opposition between cognitive intellection and mechanical execution, lies the relation between design and making. It is precisely where the reach of the imagination meets the friction of materials, or where the forces of ambition rub up against the rough edges of the world, that human life is lived.’ (2013, p.74)

4. Making and Thinking

This chapter considers the concept of *epistemic action* in the context of workshop practice. Epistemic actions are those that are performed in order to help work things out, to uncover new information and help people make decisions. The phrase was first introduced by cognitive scientists David Kirsh and Paul Maglio (1994), as they proposed that, contrary to much thinking about human behaviour, not all actions are strictly goal-directed. Whilst they acknowledge that *pragmatic actions* (actions that are intended to change the world in order to move a practitioner towards their goal) do exist, Kirsh and Maglio present the concept of epistemic actions to help discuss how some interactions with the world can be better understood as a means of thought.

As described in the previous chapter, Kirsh and Maglio's insight into the relationship of actions and thought, has helped theorists of the extended mind to question the distinction between an internal world of thought and an external world of action. Andy Clark and David Chalmers, for example, have argued that, epistemic action 'demands a spread of epistemic credit' (1998, p.8). This leads them to the conclusion that we should rethink the limits of the mind, such that it is not confined by the boundary of the skull, skin or body, but extends out into the world, as part of systems that include both people and things. From this theoretical grounding, this chapter explores the nature of epistemic action during the techniques of tool use.

I begin by critiquing what craft theorist Glenn Adamson has called 'the most compelling technical discussion of skilled work ever written' (2007, p.72), David Pye's book, *The Nature and Art of Workmanship* (1968). I argue that, whilst providing an enduringly useful account of making practice, Pye's analyses are founded upon an entirely pragmatic understanding of action. In the same way that other studies of human and world interaction have benefitted from the richer perspective afforded by theories of epistemic action (see 3.2), I aim to demonstrate what could be gained by applying this perspective to a study of workshop practice. Whilst I focus here on drawing out the pragmatic assumptions of David Pye's famous work, I also suggest that the vision of production he describes is widespread in design literature. That is to say, I use Pye's work as an exemplar to provide a more focused critique of the "default" model described in the previous chapter.

Throughout the chapter, the hammer is a recurring example, used as an archetypal tool, and the basis for understanding the epistemic nature of tool use. Through an investigation of the nature of dexterity, I argue that a hammer is at once a tool for getting a job done, and an instrument for reporting on the progress of a task. Hammer use and, I propose, techniques more generally, are both epistemic and pragmatic.

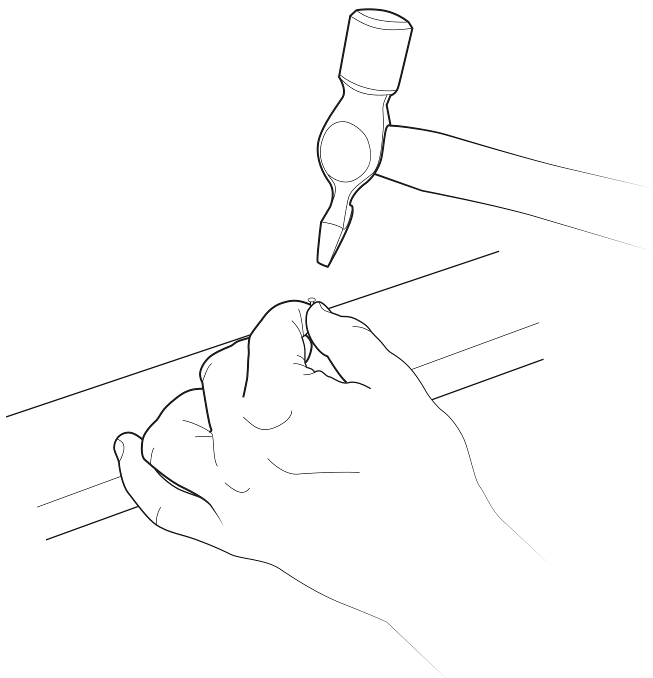
4.1. The Problem with Pye

This first section describes Pye's best known contribution to the literature of designing and making—his definition of the *workmanship of risk* and the *workmanship of certainty*. I introduce these ideas with reference to the technique of hammering in a panel pin, and develop an argument that Pye relies on an entirely pragmatic account of action.

4.1.1. Hammering a Panel Pin: The Workmanship of Risk

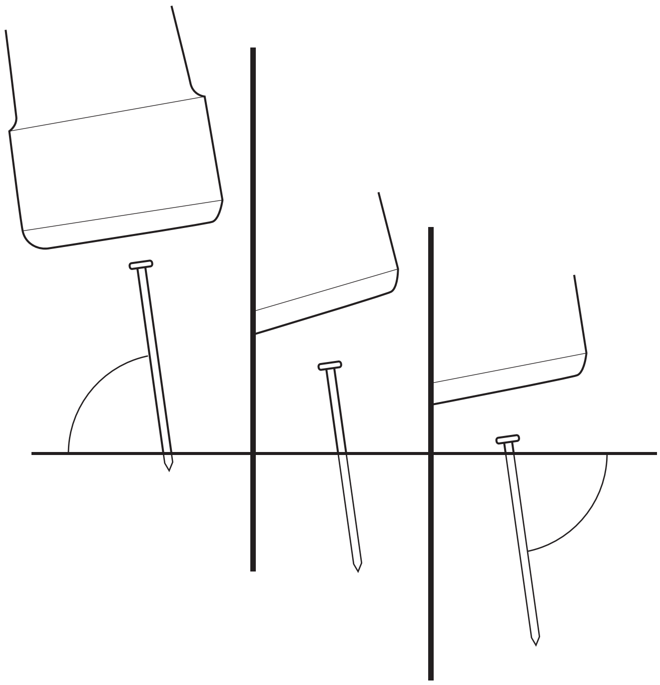
To hammer a panel pin successfully requires practice. The first challenge is to locate the pin, driving it far enough into the wood so that it no longer needs to be supported by hand. Figure 4.1 shows how the thin, rounded cross peen of a Warrington pattern hammer allows a practitioner to avoid hitting his or her own fingers during this process (Watson 1982, see p.158-9).

Figure 4. 1 Setting a pin using a Warrington pattern hammer



This stage is critical to the success of the procedure—it is with these first few taps that the position and angle of the pin becomes determined. Subsequent strikes made with the round face of the hammer can only drive the pin further along this path (Figure 4.2). Once located, blows can be delivered to the pin with more force than before.

Figure 4. 2 Repeated hammer strikes drive pin along path



At this stage, so long as the practitioner hits the pin squarely, to avoid bending it or slipping off the head, the chances of error have reduced. In rougher work where the finish is less critical, blows of increasing force are often used to drive a nail, aiming towards a final forceful strike that pushes the nail head below the wood's surface and draws a joint up tight (Ibid., see p.163). For highly finished work however, it is more common for the last few blows to be less powerful, as care is taken not to bruise the timber surrounding the pinhead. Often, the pinhead is left slightly protruding and then driven into its final position using a nail set (Figure 4.3), in an effort to avoid so-called 'French hammer marks' (Figure 4.4) that will, according to woodwork writer Aldren Watson, 'haunt the workman forever' (ibid., p.163).

Figure 4. 3 Using a nail set

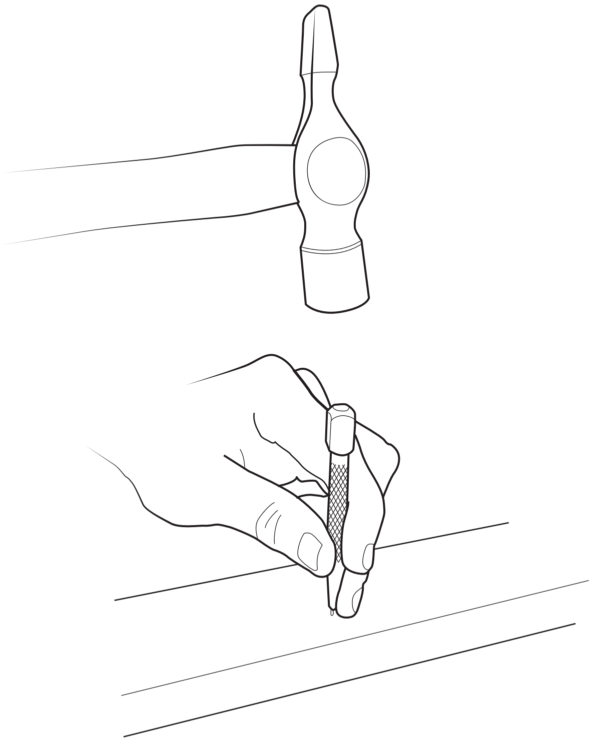
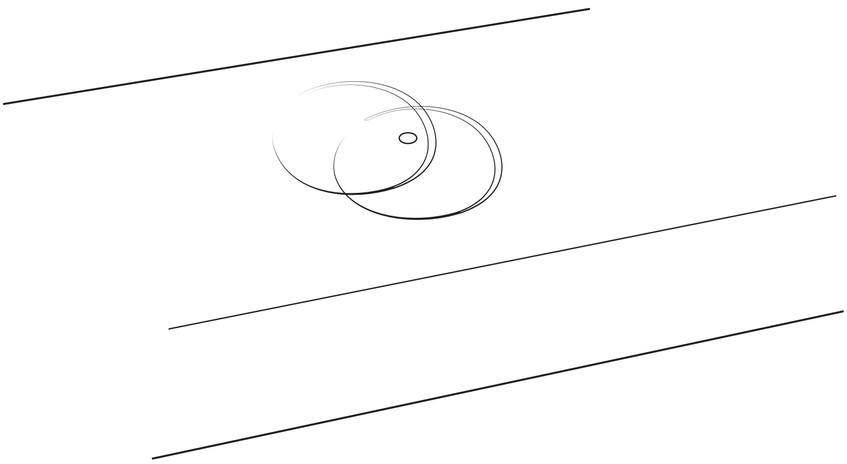


Figure 4. 4 French hammer marks



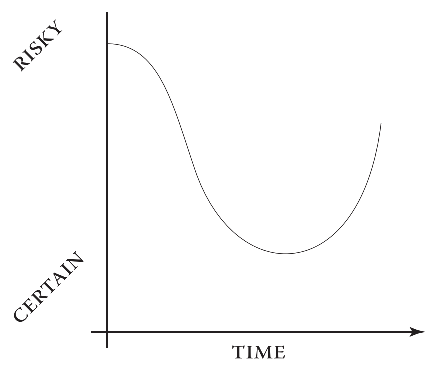
The procedure of hammering a panel pin into a piece of wood is an instance of what design and craft theorist David Pye calls the *workmanship of risk*. This phrase describes techniques wherein the quality of the result is continually at risk and relies upon the ‘judgement, dexterity and care’ (1968, p.20) of a practitioner throughout the process.

During the task of hammering a pin, the degree of risk varies. As a practitioner first locates the pin, the risk of it veering off course, or the hammer slipping and bruising the timber is high. It is at this stage that the judgement, dexterity and care about which David Pye writes are most critical. Once driven far enough into the timber so that it can support itself, however, the degree of risk drops. Tentative early blows can now become more forceful, as the pin is driven along its own length and guided by the fibres of the timber. The pin and the timber have become part of what Pye would call a determining system (Ibid., see p.21-2), a kind of jig that causes the outcome of the process to be more certain. Each blow fixes this outcome more and more firmly. As less of the pin is exposed above the timber’s surface, the chances of it bending are reduced. This state of relative certainty increases until the pinhead nears the wood’s surface, at which point the hammer strikes are eased. Whilst the determining system of pin and timber helps to guide the pin along its length, there is no such guidance to help stop it at the correct point. As the risk of French hammer marks increases then, the final few blows must reprise the tentative approach of the first.

4.1.2. The Risk Profiles of Workshop Practice

Throughout the duration of the process the degree of risk varies, creating what I term a *risk profile*. The variability of risk whilst hammering a pin may be plotted as in Figure 4.5.

Figure 4. 5 Risk profile of hammering



David Pye did not consider how the risk of a process can vary throughout its duration, but the risk profiles shown here (Figures 4.5, 4.6, and 4.7), demonstrate how his concept of risk in workmanship may be applied across various techniques.

Figure 4. 6 Risk profile of thicknessing a board with a bench plane

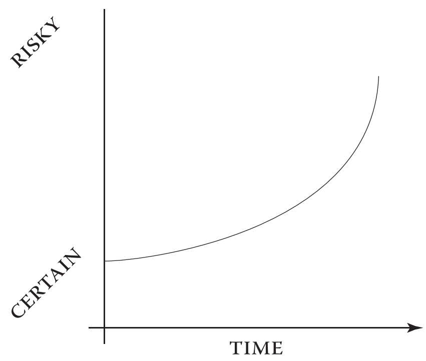
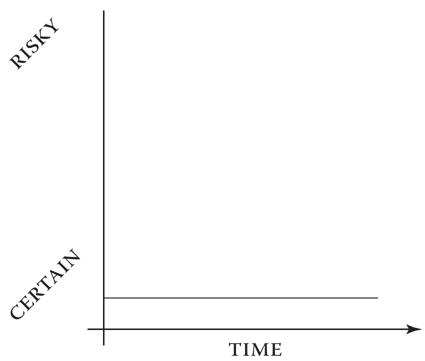


Figure 4. 7 Risk profile of cutting an MDF part on a CNC router



4.1.3. The Workmanship of Certainty

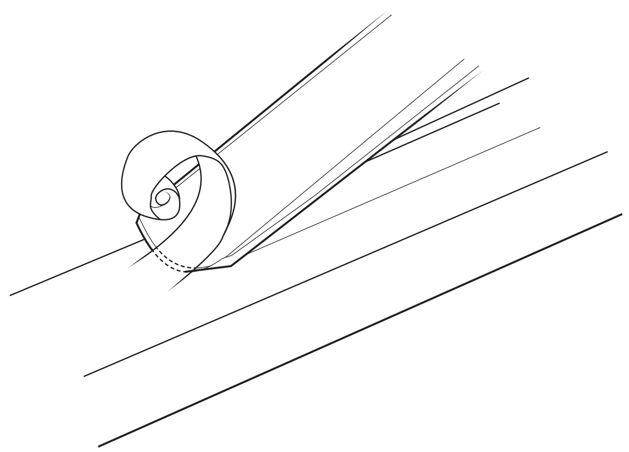
In the above risk profiles of hammering, hand planing a board of timber to thickness and cutting an MDF (a relatively homogenous material without grain) part on a CNC machine, the vertical axes run from certainty to risk. David Pye introduced the concept of a *workmanship of risk* as a contrast to what he called the *workmanship of certainty.* Where the workmanship of risk describes processes that rely on continual adjustment, care and dexterity throughout, the workmanship of certainty applies to techniques wherein the results of production are 'predetermined and unalterable once production begins' (Ibid., p.22) (see, for example, the risk profile of the CNC machine, Figure 4.7). In its most ideal state, the workmanship of certainty would exist in a fully automated factory, through which materials are processed in an entirely predetermined manner. In practice, however, this condition could never be fully realised. Even the most homogeneous materials might occasionally vary in quality, and the tools of a factory will always be subject to wear, affecting their results. As observed in the risk profiles then, techniques of production are not either 'risky' or 'certain'.

The workmanship of risk and that of certainty are not discreet categories into which techniques may be placed, but poles on a continuum of risk/certainty (Adamson 2007, see p.73). There are no absolutely certain manufacturing process and no absolutely risky ones either. And the degree of risk may vary throughout.

4.1.4. The Enduring Relevance of Pye's Analyses

Pye's workmanship of risk and certainty introduced, as craft theorist Glenn Adamson observes, a 'purposeful reframing of [the] dichotomy between craft and industry, or hand and machine' (Ibid., p.73). By defining production in terms of risk and certainty, Pye's analyses can be applied universally across different processes, scales, types of production and work environments. *The Nature and Art of Workmanship* considers all kinds of making, from the free workmanship of Pye's own wood carving practice, to the highly regulated manufacture of industrially-produced artefacts. Pye is quick to insist that even the largest volume manufacturing processes can rely on the workmanship of risk at some point. And he uses his woodworking experience to describe how the seemingly unguided chisel is inclined to travel in a certain direction, with the shape of its bevel and the grain of the timber forming a semi-determining system (1968, see p.28) (Figure 4.8). The universal nature of Pye's analyses gives them a lasting relevance and appeal. Even in the context of contemporary, digitally controlled manufacture, where one-off artefacts are made with an increasing degree of certainty, Pye's concepts remain applicable.

Figure 4. 8 The semi-determining bevel of a gouge



For Adamson, Pye's legacy is clear - his writing on workmanship constitutes 'the most compelling technical discussion of skilled work ever written' (Adamson 2007, p.72). In other reappraisals of craft's value, David Pye's ideas remain key reference points (see, for example, McCullough 1998, see p. 202-3). Contemporary woodworkers such as Peter Galbert still find a valuable link between Pye's writing and their work (2015, p. xiii). And in broader anthropological enquiry, Pye's analyses of human production are readily repurposed in studies of craft practice (see, for example, Keller & Keller 1996, see p.56; Bunn 2011, see p.24; Ingold 2011, see p.59).

It is perhaps strange that David Pye's enduring relevance to craft theory comes despite his insistence on avoiding the term *craft* almost altogether. Pye dismissed the word as loaded with the imprecise, fuzzy thinking he found in the 'doctrines' of the Arts and Crafts movement (1968, p.114). An entire chapter of *The Nature and Art of Workmanship* is in fact devoted to criticising the writings of John Ruskin and William Morris. Ever eager to discredit any valorisation of 'handwork' over 'machine work', Pye was determined that the techniques of production—be they the stroke of a chisel, or the pass of a CNC tool head—should be the subject of rational analysis, rather than indicators of a greater or lesser degree of moral virtue. Pye preferred to treat all making in purely mechanical terms. The movement of a woodworker's chisel could be analysed in the same way as a computer controlled router bit. For Pye, the hands of the woodworker guide the chisel, informed by the design (either in his mind or described on paper), in the same way that the CNC router bit's path is determined by lines of computer code. The only logical difference in these two practices, according to Pye, lies not in the involvement of the woodworker's hands, but in the degree of risk with which they are executed. The concept of risk and certainty workmanship, rather than a vague notion of craftsmanship thus provided Pye with what he considered a more logical basis upon which to base his discussion of making.

4.1.5. The Problem with Pye

As Adamson observes (2007, see p.73-4), it is this apparently logical, almost scientific basis for Pye's writing that has given it a lasting appeal. In what follows, however, I aim to demonstrate that, despite being widespread, this theory of production is a limited one. In short, I argue that Pye's account of making, as the realisation of a pre-existing design intent precludes a richer understanding of the influence of tools, techniques and materials upon the process of design. This is an argument well-rehearsed by the work reviewed in the previous chapter[1]. Here, I use Pye's writing as an exemplar of the hylomorphic assumptions dominant in design theory. The focus of my criticism lies in what I consider to be Pye's entirely pragmatic understanding of productive techniques. Under Pye's analyses, tools are always

[1] For succinct discussion, see also Ingold (2010).

employed in the pursuit of pre-formed objectives, with all action assumed to be an effort to move towards those objectives. Below, I introduce the notion of epistemic action in order to demonstrate the flaws in this account. Epistemic actions are those performed in order to help work things out, to uncover new information and help people make decisions (Kirsh and Maglio 1994).

Before introducing the concept of epistemic action in more detail, however, I wish to introduce two more of Pye's concepts, regarding *skill* and *good workmanship*. I discuss these subjects for two reasons; 1) to reinforce the point of Pye's reliance on a dualism of thought and action, and 2) to also admit that, despite their failings, Pye's concepts and definitions have a powerful common-sense appeal. It is not the aim of this chapter to wholeheartedly refute Pye's contribution. Ultimately, I aim to demonstrate how his work might be complemented by a more nuanced understanding of the relationship between thought and action, or, more specifically, designing and making. This understanding will then, throughout the remainder of this thesis, become the foundation for a novel interpretation of workshop practice as a place of design.

4.1.6. Pye on Skill

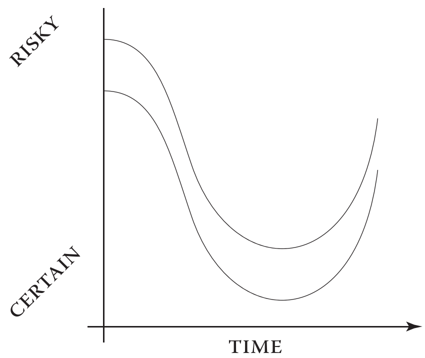
Attempts to discredit the moralistic rhetoric of the Arts and Crafts movement led David Pye to challenge the terminology of craft and craftsmanship on many fronts. For Pye, the word *skill* was as troublesome as craft. It was a 'thought-preventer' (1968, p.20) that was best avoided, because it could mean whatever one wanted it to mean. Throughout his discussion of the nature of workmanship, Pye attempted to recast skill not as something 'with a deep spiritual value of a somewhat mystical kind' (Ibid.), but as the mechanical control of movement.

For Pye, the main problem with the word skill was its imprecision. It could be invoked to describe very different kinds of knowledge, even within the same domain of production. In blacksmithing, for example, we might talk both of the skill with which a smith wields their hammer, and the skill with which they judge the working temperature of iron. 'Skill' can therefore be applied variously, to describe both a kind of physical dexterity (in hammer use) and mental know-how (the judgement of temperature). Whilst the former would be an instance of Pye's workmanship of risk, the knowledge of working temperatures would, for Pye, be something that could be measured and specified in words and drawings and therefore a matter of design, rather than workmanship.

Glenn Adamson has since observed that, if there is any place in *The Nature and Art of Workmanship* for the notion of skill, it is limited only to the dexterity upon which the workmanship of risk relies (2007, see p.73). This is the manual dexterity required to guide a tool along a certain path. Under this understanding, dexterity is the human equivalent of the predetermined motion of a machine. 'All workmen using the workmanship of risk', writes Pye, 'are constantly devising ways to limit the risk by using things such as jigs and templates. If you want to draw a straight line with your pen, you do not go at it freehand, but use a ruler, that is to say, a jig. There is still a risk of blots and kinks, but less risk. You could even do your writing with a stencil, a more exacting jig, but it would be slow' (1968, p.21). For Pye, there is a clear equivalence between the human capacity for dexterity and the determining jigs of machines. On this understanding, dexterity, once developed in the skilled practitioner is a means of limiting risk. Just as jigs allow an action to proceed in a predetermined way, *The Nature and Art of Workmanship* considers dexterity to be the ability to control movement according to a specific intent (see also Pye 1978, p.50-3).

This account of skill may be illustrated by overlaying the risk profiles of a novice and expert hammer user (Figure 4.9). Whilst the degree of risk might vary similarly throughout the task, it is always higher for the novice. Without the experience of repeated practice, there is a greater likelihood that the results of hammering will deviate from the intended outcome. It is this model of production, wherein either human dexterity or the predetermined motion of a machine is put to work in the pursuit of a pre-existing design that underpins all David Pye's analyses of making practice.

Figure 4. 9 The risk profiles of novice and expert hammer users



4.1.7. Pye on 'Good Workmanship'

The application of workmanship in pursuit of pre-existing intentions is also clearly expressed in David Pye's definition of "good workmanship". This is the nearest thing to a discussion of what might more commonly be called craftsmanship that Pye offers. It is Pye's version of how things can be made well.

'Good workmanship' writes Pye, 'is that which carries out or improves upon the intended design. Bad workmanship is that which fails to do so and thwarts the design.' (1968, p.30). In *The Nature and Art of Workmanship*, Pye demonstrates how such a definition accounts for the good workmanship he finds both in the regularity of mass-produced drinks cans and the quickly carved relief of the expert woodworker. Eager to account for all such instances of what he considers good workmanship, Pye defines the quality of workmanship not with reference to the means of production (and the degree to which they rely on manual dexterity), but by the accuracy with which results match design intentions. This is part of Pye's argument against the valorisation of handwork. Pye's idea of good workmanship—as that which realises or improves upon design intention—brings a straightforwardness to matters of production. If something was meant to be smooth and it is smooth, that's good workmanship. And if it was meant to be rough and it is, that's good too. It does not matter how such results are achieved, only that workmanship has been successfully applied in the pursuit of a pre-existing design. To judge workmanship against design intent is to use a method of assessment that can account for both the qualities of mass production and the intentionally irregular results of hand work.

The common-sense appeal of this definition is inarguable. Such an understanding is key to industrial quality assurance practices (Garvin 1984) and the everyday assessments people make of goods (see, for example, Forslund et al. 2013). There are also circumstances that are commonly agreed to be the result of poor workmanship. If we return, for example, to the case of French hammer marks described at the start of this chapter, the bruising of timber around a pin head is acknowledged as an unwanted consequence of poor hammer technique. A lack of dexterity, or the lack of care taken to use a nail set, results in a lasting impression. Whilst there must be very few, if any, occasions when French hammer marks can harm the practical efficacy of a piece of woodwork, it is nonetheless widely regarded as evidence of poor workmanship. The judgement of workmanship here is based on the inference that the hammer blows were not intended to bruise the timber. The workmanship may be judged to be bad because there is a conflict between the intended and actual results of hammering[2].

[2] In this definition of good workmanship, we see how Pye takes a hylomorphic model of how things are made and develops it into a definition of how things are made well. I find philosopher Andrew Harrison to offer an interesting alternative, perhaps more aligned to the opposing understanding of production from the previous chapter; '[A] bad maker of something is one who does not quite know what he is doing, sometimes, but not always in

4.1.8. The Separation of Workmanship from Design

David Pye's observations on skill and good workmanship provide an insight into the foundations of his account of designing and making. The technical clarity to which Pye aspires in his definitions is, as design and craft theorists Christopher Frayling and Helen Snowdon describe, made possible only by a separation of the processes of design from those of workmanship (1982, see p.19). In order to describe the risk or certainty with which tools may achieve a predetermined objective, to understand skill as the mechanical constraint of movement, or to judge workmanship exclusively with reference to intentions, it is necessary for Pye to divorce the techniques of making from any role in processes of design. This account of production divides designing and making along the same lines as many other scholars (as seen in the previous chapter). And it is perhaps made most obvious in Pye's work by the division of these subjects into two separate books.

David Pye's *The Nature and Art of Workmanship* was preceded by his book *The Nature of Design*. These two books were intended by Pye to compliment one another, describing what he understood to be the two facets of the human-made environment—the design of things and their manufacture. As Frayling and Snowdon discuss (1982), by the time Pye had revised and republished *The Nature of Design* (as *The Nature and Aesthetics of Design* in 1978), he had made firm his decision about the concept of skill and its application in matters of production. If dividing the discussion of design and workmanship into two separate books wasn't enough, Pye affirms that it is 'necessary to differentiate between skill as the exercising of constraint on movement and "skill" as know-how, for know-how, in making, is design. Thus according to the terms of this book one should say that anybody has skill enough to build a good dry-stone wall but that few know how to design one, for the placing of the stones is a matter of knowledge and judgement, not of dexterity' (1978, p.52). Pye would rather not discuss dry-stone walling as a skilled activity, because it does not demand a high degree of physical dexterity. If someone can lift and place a stone, then, with instruction, they should be able to make a good wall. Dry-stone walling demands a kind of knowledge that can be described in words, and, for Pye, this kind of knowledge is a matter of design.

4.1.9. Pye's Pragmatic Understanding of Action

David Pye's descriptions of the workmanship of risk and certainty, and good workmanship have an everyday validity. As discussed above, they offer an enduringly relevant means of

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the sense that he does not know what he is setting out to achieve, but always in the sense that he is not paying attention to what he is doing.' (1978, p.190) analysing physical procedures. But I now aim to demonstrate that his account of production is not as comprehensive as it might seem. This argument rests on Pye's failure to see the potential for making practice, and action more generally, to operate in anything other than a pragmatic way. That is to say that Pye assumes all action to be intended to move a practitioner towards a goal.

In Pye's account of dry-stone walling, for example, the critical type of knowledge is mental know-how, as divorced from the relatively straightforward action of picking up and placing stones. It is assumed that these actions are employed to enact instructions sent out from an internal world of thought. In practice, however, action is not only used in this way. It is not only part of a one-directional path from an internal idea towards a pre-determined external result. In the previous chapter's example of jigsaw assembly (which we could consider analogous to the work of dry-stone wall building), Andy Clark has observed that one does not sit staring at puzzle pieces in an effort to develop a plan of action (1997, see p.36) (see 3.2.2). No one imagines that it is possible to consider all the required moves and piece rotations in your head and then enact them with successful results. What the successful jigsaw player must do is pick pieces up, spin them around, and try things out for fit. The completion of a jigsaw in the real-world proceeds by way of step-by-step transformations, which give both pragmatic results (the correct fitting of a piece) and an improved understanding of the task (as in the grouping of similarly coloured pieces). Even if we assume that the dry-stone wall builder has a clear vision of the ultimate outcome (just as there is only one correct solution to a jigsaw puzzle), they must still use action to both build the wall and improve their understanding of the task. Actions like sensing the weight of a stone, rotating it to assess its suitability, physically sorting stones into types, or checking their balance as they are placed can all be considered *epistemic* in their nature. It is under this kind of interrogation that the sharply demarcated boundary between design and workmanship, thinking and doing, or know-how and skill, begins to falter. Upon the dualist foundation of Pye's definitions, there is no room for epistemic action.

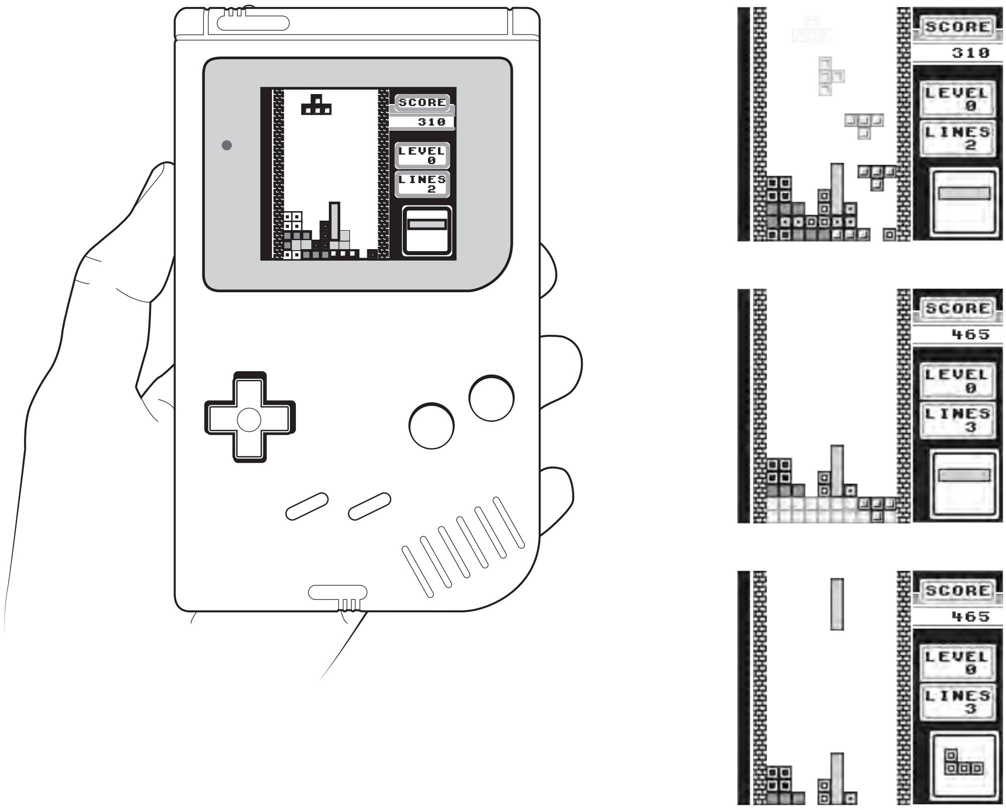
4.2. Pragmatic and Epistemic Actions

4.2.1. Epistemic Action

Epistemic action is a term introduced by David Kirsh and Paul Maglio, in order to distinguish between two types of actions—those that aim to change the state of the world to accomplish a goal (pragmatic actions), and those that aim to change the state of the world in order to support cognition (epistemic actions). Epistemic actions are those taken 'to change the world in order to simplify the problem-solving task' (1994, p.513). In an influential paper, Kirsh and Maglio propose the concept of epistemic action to redress what they saw as a failure in their field of cognitive science. Kirsh and Maglio aimed to challenge planning-based approaches to cognition, which see action as fundamentally pragmatic, and where the 'only reason to act was for advancement in the physical world' (Ibid., p.526). In this view, thinking always proceeds action and action can, at best, lead someone to re-evaluate their conclusions. Crucially, and herein lies Kirsh and Maglio's main criticism, in solely pragmatic accounts of human behaviour, action is never undertaken 'in order to alter the way cognition proceeds […,] cognition is logically prior: Cognition is necessary for intelligent action, but action is never necessary for intelligent cognition' (Ibid., p.526). The tendency to prioritise cognition over action, therefore assuming every action to be pragmatic, can be understood as a consequence of the folk model of cognition discussed in the previous chapter (3.2.1). And it is the same tendency we find in David Pye's writing above.

Kirsh and Maglio supported their definition of pragmatic and epistemic action by reporting on a study of expert Tetris players, which showed how rotating puzzle pieces on a video game screen aids cognition and decision making (Figure 4.10). In Kirsh and Maglio's study, piece rotations and movements during experts' games show evidence of actions being used not to advance towards the game's goal directly, but to aid the decision-making ability of players. As soon as a zoid comes into partial view at the top of the screen, experts made seemingly unnecessary rotations and lateral movements. Kirsh and Maglio observed that these apparently needless transformations are in fact employed as useful strategies that allow players to quickly determine the type of zoid in play and consider how it might be fitted to the existing stack. Another common sequence of epistemic action also sees zoids moved to the edge of the screen and then moved back again, to help confirm their horizontal position. In expert Tetris play then, rotating and moving a piece on screen is not always done to advance towards the goals of the game, but can be used to test potential means of action, speed up decision making and reduce errors. 'The point of [epistemic] actions', conclude Kirsh and Maglio, 'is not for the effect they have on the environment as much as for the effect they have on the agent' (Ibid., p.546).

Figure 4. 10 Tetris on the Gameboy



Although it has been widely cited as a valuable contribution to work on extended and distributed cognition, it should be noted that Kirsh and Maglio's ideas were not without precedent. In, for example philosopher John Dewey's concept of "doing for the sake of knowing", we find a similar idea (1929, see p.84-5)[3].

4.2.2. The Significance of Epistemic Action & Extended Mind to this study

The laboratory-like example of Tetris gameplay found in Kirsh and Maglio's original study is profoundly rule-bound (the idea of advancement in the physical world being easily determinable with reference to the task's objectives). In situations where the results are less absolutely prescribed (such as in the open-ended problems of designing and making), however, I suggest that epistemic action has an equally, if not more, important role. Indeed, in practices aimed towards working out what things should be like, the whole exercise can be understood as one of discovery.

[3] Unfortunately for the present discussion, Dewey is associated with the philosophy of pragmatism, but this should not be confused with the less specialist application of the word "pragmatic" here.

In the remainder of this chapter, I begin to consider epistemic action and theories of extended mind in the context of workshop practice. Throughout the chapter thus far, I have used David Pye's writing as an exemplar of the pragmatic assumptions prevalent in design and making theory. Alternative accounts such as Henrik Gedenryd's (see 3.2.1) have gone someway to demonstrating the insight that might come from challenging these assumptions. Once understood as an integral part of cognitive systems, the manipulation of the world can be understood not just in pragmatic terms, as a way to impose fully formed ideas upon materials, but as a means of working things out. Through studying the tools and techniques of making practice in detail, and bestowing them with "epsitemic credit", I now aim to develop a novel and useful description of techniques as simultaneously pragmatic and epistemic. This description will then become the foundation for the rest of the thesis' investigation of epistemic character.

4.3. What's a Hammer For?: Tool Use is Both Pragmatic and Epistemic

In an effort to demonstrate how my criticism of Pye and the above discussion of epistemic actions is relevant to designing and making practice, I conclude this chapter by returning to the subject of hammer use. The aim is to complement Pye's useful, but wholly pragmatic, account of human production with an examination of the epistemic nature of tool use. Ultimately, I suggest that the tools and techniques of designing and making may be understood not only by the degree of certainty with which they may achieve pre-conceived ends, but by the ways in which the support epistemic action. Before introducing the hammer, however, I first revisit a subject that Pye preferred to avoid - the nature of skill. Through studying skill in more detail, I aim to develop a description of tool use that, inspired by the notion of epistemic action, captures its simultaneously epistemic and pragmatic nature.

The inspiration for this investigation comes from neurophysiologist Nikolai Bernstein's classic account of the development of dexterity, *On Dexterity and Its Development* (1996). By considering the nature of skill (or dexterity—having adopted Pye's physical interpretation, I now treat the terms as equivalent throughout this chapter) and its development in more detail, I hope to demonstrate that epistemic action occurs at every occasion of tool use.

This section of the chapter concludes by me addressing the question 'what is a hammer for?'. Based upon Bernstein's account of dexterity, I aim to show that hammers simultaneously support both epistemic and pragmatic actions. Whilst the hammer becomes an archetypal tool upon which to base this investigation, the intention is that this analysis can also be applied more generally. This more general account of the epistemic character of tool use is developed in the next chapter.

4.3.1. The Development of Dexterity

The control of movement required for David Pye's workmanship of risk is the kind developed over time and through experience. The woodworker hammering a pin does so with precision only because they have spent time rehearsing similar actions on past jobs. It is uncontroversial to say that all skilled work, or all workmanship of the risky kind, requires practice and repetition. Returning to the risk profile of hammering a pin introduced above, when we overlay the profile of an expert woodworker and a novice (Figure 4.9), we can see that, whilst the shape of the curve might remain constant as the phases of higher risk are similarly located, the degree of this risk is lessened with practice. In David Pye's interpretation, this would be because the expert woodworker has developed a dexterity that allows them to precisely control the movement of their hammer swing. How exactly this dexterity operates, or how the process of becoming dexterous occurs, however, were not questions which David Pye tackled directly. For a more detailed analysis of the nature of dexterity, I turn to neurophysiologist Nikolai Bernstein's pioneering book, *On Dexterity and Its Development*. Written in the 1920s, but only published posthumously in 1996, *On Dexterity and Its Development* has become a classic text for the subject of skill acquisition.

4.3.2. Nikolai Bernstein on Dexterity

Nikolai Bernstein challenged the common assumption that learning involves repetition in order to fix a set pattern of movement in memory. The traditional theory that Bernstein disputed understood skilful action to be the result of fixed commands, sent out from the central nervous centre and enacted by the muscles. In this model, the repetition of action necessary for the development of skill was a repetition of these commands, until a 'specific neural pathway is well established' (Reed and Bril 1996, p.436). As Bernstein pointed out, however, there is a failing to this logic. People begin learning skills because they can't do them—at the beginning of this process 'the only thing available for imprinting is wrong, clumsy movements' (Bernstein 1996, p.204).

Bernstein's work offered an alternative, more nuanced account of motor control and skill acquisition. Rather than understanding the control of movement to be dominated by learned commands sent out from motor control systems to the muscles, Bernstein proposed that the key requirement of dexterous activity lies in a responsiveness to feedback from sensory systems (ibid., see p.25-44). It is not pre-learned motor control signals that guide skilful action, argued Bernstein, but continual corrective movements made in response to sensory awareness. The important observation that helped Bernstein arrive at this insight is that, unlike the pre-determined motion of mechanical equipment, human movement is difficult to control in a predictable way. Because of the multiple degrees of freedom of human limbs and the elasticity of muscles, identical control signals would not guarantee identical results[4]. The only way to overcome such unpredictability, observed Bernstein, is to develop an ability to respond to sensory inputs throughout a task.

Bernstein finds an everyday example of sensory feedback guiding dexterous work in knot tying. Whilst under normal conditions knots are easily tied by practiced individuals, if the same movements are attempted with cold hands, it becomes more difficult. This is not, notes

[4] See also van lngen Schenau and van Soest (1996)

Bernstein, due to any loss of muscular strength. At the temperatures where knot tying becomes more difficult, the muscles controlling the hands' movements can still deliver the same maximum force. The problems are caused by the reduction in the 'tactile sensitivity in hands and fingers' (1996, p.43). The lack of feedback from cold hands hinders the ability to make accurate movements. This, concludes Bernstein, is because accurate movements are not the result of fixed patterns of motor control, but are made in response to a sensitivity to the conditions of an emergent task.

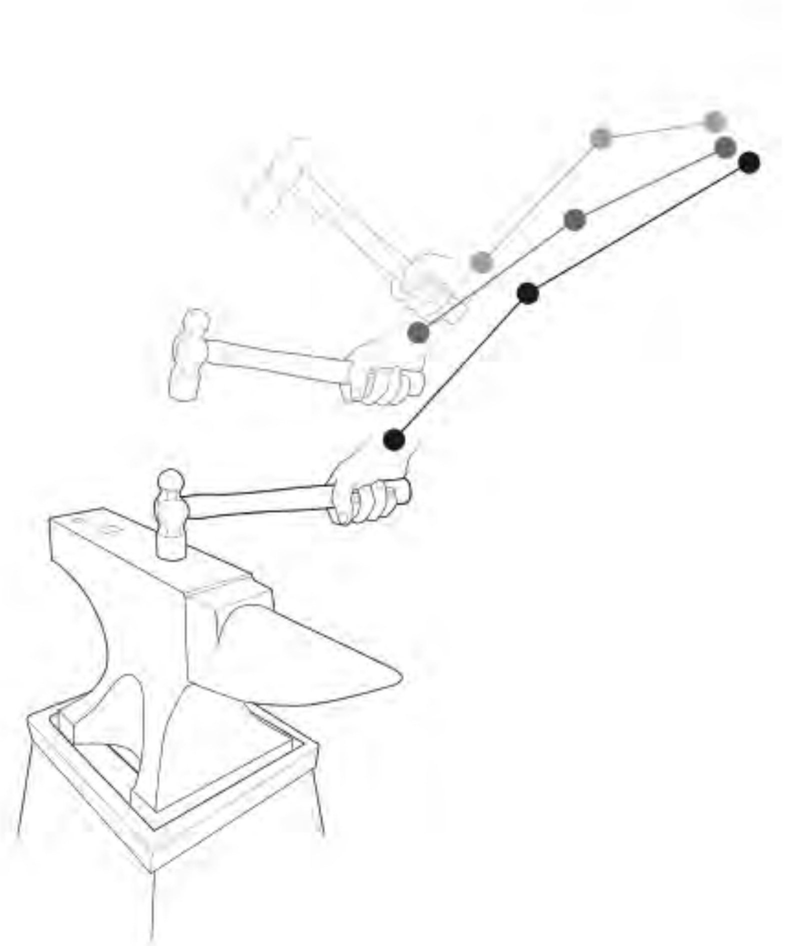
4.3.3. Repetition without repetition

What then, do people repeat when they practice to become skilled? If not "beating a neural pathway" to help guarantee a predictable movement, what is the repetition for? Bernstein proposed that the repetition required of skill development 'is necessary in order to *solve a motor problem* many times (better and better) and to *find the best ways* of solving it' (ibid., p.176, emphases in original). This is what Bernstein termed 'repetition without repetition' (ibid., p.205) and it is the key to his theory of skill development. Rather than repeating the 'means for solving' a motor problem, skilled practice relies on the repetition of the process of finding the solution (ibid., p.206). Solving the same problem again and again, in the context of variable external (environmental) and internal (e.g. with respect to muscle elasticity) states allows practitioners to develop an enhanced awareness to sensory feedback during action, and learn how to correct their movement accordingly.

4.3.4. Bernstein and The Blacksmith's Hammer

In an interesting overlapping of interests, both David Pye and Nickolai Bernstein considered the dexterity of a blacksmith. Bernstein chose to study the technique of expert blacksmiths in order to gain insight into how exactly this skill is developed (Gurfinkel and Cordo 1998). Using the then novel technique of high speed photography, Bernstein tracked the movement of experienced blacksmiths' arms and their hammers whilst they repeatedly hit the same point on an anvil (Figure 4.11).

Figure 4. 11 The trajectory of a blacksmith's swing



Plotting the trajectories of the arm joints and the face of the hammer, Bernstein identified that, although the movement of the hammerhead was highly consistent across multiple strikes, the arrangement of the arm joints varied each time. The outcome of the blacksmith's action was repeatable, even though the means by which this solution was arrived at changed with every strike. This was evidence to Bernstein that the smith had not become skilled by internalising a repeatable programme for their hammer swing. The years spent developing precise hammering skill were not, it appeared, used to develop a specific pattern of muscle and joint movement. The blacksmiths of Bernstein's experiment were instead experts at solving the problem of delivering the hammer face to exactly the same point, despite the variable elasticity of their muscles and the unpredictable recoil of the tool. At first, this seems a strange paradox—how can it be the motion of the hammer that is reproducible, rather than the motion of the blacksmith's arm itself (Ingold 2001, see p.21; Latash 1996, see p.286)? But if, as Bernstein describes, the essence of dexterity lies in a sensitivity to ever changing, emergent and unpredictable internal and external states, the *repetition without repetition* witnessed in the study of blacksmiths is a necessary condition of skilled activity. The consequence of this repeated solving is an enhanced sensitivity to the progress of an emergent task and, therefore, an improved ability to apply force with precision.

4.3.5. The Sweet Spot of a Hammer

Reflecting more recently on the legacy and relevance of Bernstein's work on dexterity, physiologist Mark Latash has introduced the idea of the *working point* as a way of describing the parts of motor systems which are 'most important' throughout a task (1996, p.287). This idea helps to illuminate Bernstein's discussion of how practitioners are able to consistently control the movement of one point, whilst the means by which this movement is achieved may vary. As a practitioner tunes their senses to a particular task, suggests Latash, the motion of the working point becomes the focus throughout the action.

In the example of hammering a pin, we can define the working point to be the hammer's centre of percussion. This is the 'sweet spot' on the hammer's face which, when used to strike an object, provides practitioners with the 'satisfying feeling' (Carello et al. 1998, p.307) of the tool working most efficiently. If the face of the hammer impacts the pinhead in just the right way, the 'haptic subsystem of dynamic touch' (Turvey and Carello 1995, p.401; see also, Gibson 1979) informs the practitioner that the sweet spot has been utilised. As the hammer's face and the pinhead then travel together for the duration of the impact, the movement may be sensed, so that the next swing and strike can be adjusted accordingly. If the pin seems to be veering one way or the other, it can be corrected with the next blow.

4.3.6. Tool use is both epistemic and pragmatic

I hope now to make clear the parallels between Bernstein's discussion of skilled activity and Kirsh and Maglio's description of epistemic action. In both, we find criticisms of one-way interpretations of action. Bernstein refutes the idea that skilled hammer movements are the result of fixed, repeatable patterns sent outwards from the nervous system to the muscles. And Kirsh and Maglio demonstrate that expert Tetris players do not work out solutions in their head and then input those solutions into the game. In both Bernstein's study of hammering and Kirsh and Maglio's analysis of Tetris then, responding to sensory feedback is key to the tasks' success. Throughout a game of Tetris, players use action not just to complete the game's objectives, but also to help work out the best moves. The rotation and lateral movement of zoids is used both to generate sensory feedback (to help cognition) and to achieve success in the game. Similarly, throughout the process of hammering, with every swing and strike, a practitioner must be continually alert and perceptive to feedback. The strike of the hammer, in addition to achieving a pragmatic result in the world, provides sensorial feedback. As it is shaping metal, knocking in nails, or fracturing rocks, the hammer also reports on the progress of these tasks. In both Tetris gameplay and skilled hammer use, we find what Tim Ingold calls a 'coupling of perception and action' (2011, p.58). It is this coupling that erodes the boundary between thought and action, or, as theorists of the extended mind would argue, between mind and world. And, as I now go on to argue, it offers a useful insight into the nature of tool use as simultaneously pragmatic and epistemic.

4.3.7. The Function of a Hammer

The question, 'what is a hammer for?' prompts us to understand the object teleologically. Teleological reasoning, or asking what things are *for*, is the result of a tendency to assume that objects exist for a purpose (Kelemen 1999). Whilst sensible in the context of human made tools, psychologist Deborah Kelemen describes how this kind of reasoning is often over-privileged by children, who are 'prone to a "promiscuous teleology", in which artefacts and natural objects of all types are viewed as existing for a function' (ibid. p.461). Pioneering child psychologist Georges Henri Luquet's offers an anecdote of a child describing objects not by their name, but by what they do. A chair thus becomes 'for sitting on', a plate 'for eating on' and so on. In an attempt to catch the child out, Luquet asked what a slug was for, and was 'left feeling completely sheepish when she said that it was for squashing' (1913, quoted in Knappett 2005, p.44).

Although adults might generally have a more nuanced understanding of function than the slug-squishing child of Luquet's example, I hope to show that the epistemic nature of tool use introduced above might allow us to develop an even richer account of the function of hammers. In short, I wish to argue that a hammer, just as it might usually be considered *for* achieving pragmatic results (knocking in a nail etc.), is also *for* reporting on the progress of the task of hammering. In addressing the question 'what is a hammer for?' I aim to demonstrate the simultaneously pragmatic and epistemic nature of tool use.

Bernstein's observations on dexterity are fundamental to this description of the function of tools. If we are to ignore Bernstein's contribution and assume hammering to be the enacting of a pre-programmed, learned sequence of movement, then the effectiveness of a hammer would depend little upon the quality of feedback it provides throughout the process. The best hammer might simply be the one that gets the job done as quickly as possible. But if we acknowledge the requirement of a hammer user to be continually aware of, and respondent to, the sensory feedback of their tool, then the quality of that feedback is critical to success. This point is perhaps obvious to experienced users of tools, where the feeling of working a material can be tangibly deadened by, for example, even a subtly dulled cutting edge.

Observing the tendency to rely on simplistic accounts of tool function, Lars Spuybroek writes that '[t]ools have persistently been misrepresented through the notion of use, which defines action as fixed purpose' (2011, p.49). Such limited, 'design-centric' attitudes to function follow, as Theodora Vardouli observes, a 'long intellectual tradition of functionalist theory' (2015, p.140), wherein the function of things are determined by the designer(s) in advance of their production and use. Functions, like the action about which Spuybroek writes, are thus fixed, well-defined and 'have little to do with the actual use of the object' (2015, p.141; see also Preston 1998; Houkes and Vermaas 2006).

4.3.8. Proper Functions and System Functions

Different types of hammers are intended for different purposes—claw hammers drive and pull nails, geology hammers split rocks and ball-pein hammers work metal. These descriptions are what philosopher of material culture Beth Preston would call *proper functions* (1998). They are the purposes for which the objects are reproduced—sensible answers made in the mode of teleological reasoning. And that might be the end of the story, were it not for the fact that, whatever functions we have in mind whilst designing tools, they almost always perform a number of other functions that we do not ask of them.

Hammers, for example, make a noise when hammering. It would not be considered a proper function of hammers to make noise, but if brought into use as a door knocker, a hammer's propensity to make a noise might be repurposed as its primary function. Preston believes there is a distinction to made, however, between this occasional use of objects in non-standard ways and those uses for which they are reproduced. Accompanying her concept of *proper function*, then, comes the complementary idea of *system function*. A system function is a function that an object can be used for as part of a system of other objects, but it is not the function for which something is reproduced.

The existence of system functions highlights the limitations of teleological reasoning and the design-centric accounts of function criticised by Vardouli (2015). All things may be brought into use in ways that were not anticipated in advance of their production. To describe a chair as "for sitting on", for example, does not account for it being brought into use as a step upon which to stand when changing a light bulb. In the language of cognitive scientist and design theorist Don Norman, it can be said that system functions are a result of things 'affording' (1998) a variety of potential uses (see 5.1 for more on this idea). Owing to their size, weight, shape or other properties, new system functions may be discovered throughout the life of an artefact.

4.3.9. What are Tools for?

Returning to the example of the hammer, we may now consider what it is *for* in more detail. The proper function of the Warrington pattern hammer studied above is to drive pins into wood. Because of its thin cross peen, the Warrington is particularly adept at setting small pins whilst avoiding hitting your thumb. And its polished, convex face makes it appropriate for highly finished work, where there is a desire not to mark the timber. Until we consider the Warrington's ability to be used as a door knocker, the fact that the hammer makes a noise, might not be considered part of its useful, proper, function. But in the real world, during the practices of tool use, it's often very difficult to identify which properties, or affordances, of objects are useful and which aren't. When hitting things with a hammer, the sound it is making is extremely useful—it offers the practitioner valuable feedback on the task. The skilled practitioner listens attentively to the sound of the hammer, adjusting their technique accordingly. So, whilst tool designers might agree that the 'proper' function of a hammer is not to make a noise, during skilled hammer use, the sound provides an important kind of feedback. This sound must, therefore be considered as a part of the hammer's function. As the tool is skilfully brought into use amongst a system of other things—including the pin, the workbench, pieces of timber, and the practitioner themselves—any description of a hammer's function must take into account both its pragmatic effects and its epistemic potential. The function of a hammer lies not only in its efficacy at achieving goals, but also in the feedback it offers, as an instrument to measure the progress of those goals. The hammer must simultaneously support both pragmatic action (as part of the effort to drive the pin into the timber) and epistemic action (by providing a report on how the task is going). From this observation on the specifics of hammer use, we could extrapolate more generally, and state that tools are at once *for doing things* and also *instruments for sensing how those things are going*.

4.4. Summary

The aim of this chapter has been to continue the exploration of extended mind theory, and begin to apply the idea that epistemic credit should be shared across the tools and techniques of workshop practice. Beginning with a critique of David Pye's writing on the nature of workmanship, I suggested that, despite his enduring relevance across disciplines, Pye's work is reliant upon the same flawed assumptions found in the previous chapter. I have used Pye's approach as an exemplar of a general tendency in theory on designing and making to assume all action to be goal-directed. I introduced the idea of epistemic actions in order to both highlight this tendency and to demonstrate what might be gained by a more nuanced understanding of making practice, as simultaneously epistemic and pragmatic. Fundamental to this understanding is an account of tools as simultaneously *for doing things* and also *for finding out how those things are going*. It is this point which forms the basis for the next chapter's investigation of *epistemic character*, throughout which I suggest we supplement David Pye's account of the risk or certainty with which tools and techniques achieve results, with a description of how they support epistemic action. Just as techniques may have variously risky and certain characters, I aim to show that they may also be considered according to their differing epistemic characters.

Ultimately, I hope to demonstrate how my account of workshop practice might complement David Pye's analyses. In particular, I am eager to show how an appreciation of the epistemic character of workshop practice can remain consistent with Pye's determination that there should be no unwarranted valorising of 'hand' over 'machine' work. Whilst the discussion of hammer use throughout this chapter might appear to prioritise what, in Pye's terminology, can be considered a riskier technique of production, I do this only to offer what I consider an easily-understood instance of epistemic action in practice. I do not intend to reinstate the primacy of handwork dismissed by Pye.

5. The Epistemic Character of Techniques

In the previous chapter, I introduced the idea that tools are simultaneously for achieving things and for finding out how those things are going. The concept of epistemic action helped to frame making practice not just as a way of realizing antecedent ideas, but as a way of working out what things should be like. In this chapter, I continue on this theme by investigating the idea that, in addition to their pragmatic capacity to complete tasks, tools and their associated techniques have an *epistemic character*. In what follows, I aim to describe what I mean by epistemic character, and suggest ways in which we might begin to identify the epistemic character of the techniques.

The chapter is structured around three questions that might be asked in order to interrogate a technique's epistemic character. These questions are: *What questions does the technique pose?*; *What is the 'step-character' of the technique?*; and *What is the nature of the emergent result throughout the technique?* For each of these questions, I present a study of techniques, in order to show how they may be asked in specific contexts.

The underlying motivation for this chapter is the idea that techniques might be more or less suited to working things out. Or, they might structure decision making in such a way as to promote certain considerations and neglect others. Whilst this chapter begins my discussion of these issues, they are further explored in Chapters 6 and 7.

I have developed the ideas in this chapter through using the techniques described first-hand (according to the method outlined in 2.6) and combining my reflections on their use with the writing of others. I therefore describe the three questions of epistemic character with continual reference to other literature: the investigation of techniques *posing questions* draws on the idea of a "conversation with materials" (Schön 1983, 1994; Link 1975; Gedenryd 1998); the question of *step-character* looks to literature on the temporal arrangement of techniques (Ingold 2011; Malafouris 2013); and I discuss the *nature of an emergent result* with reference to the idea of "material agency" and Andrew Pickering's contrast of the "performative" and "representational" idioms (1995; 2008). I believe linking these ideas to the specifics of practice helps to illustrate their relevance to the concept of epistemic character, and design theory more generally.

The techniques described in this chapter are drawn from the practice of using rulers and dividers, carving a wooden spoon, and making paper planes. I have chosen these examples for three reasons: 1) they are (like the previous study of hammer use) relatively simple to describe, and may be readily understood from a position of unfamiliarity; 2) I am myself familiar with the techniques; and 3) owing to their careful selection, they help to illustrate the specific interests of each of the three questions.

This last point is important. It follows from this "targeted" approach to technique selection that I am not suggesting that these questions will be equally valuable when interrogating the epistemic character of any and all techniques. It might be that one of the three questions proves to be either highly valuable or largely redundant in the context of a particular technique. Indeed, the reason I present these ideas as "questions", rather than "features" or "elements" is to clarify that I am not presenting a detailed anatomy of epistemic character, but an investigation of it. This is to acknowledge that the ideas below are proposed as a starting point, from which a more comprehensive exploration of the subject could follow. Whilst my examples are focused on the specifics of particular techniques then, I hope they might serve as examples of the kinds of investigations that could be performed more generally.

Although the detailed features of epistemic character might remain in a nascent state, I have nonetheless (as previously described in 2.6.14) developed a definition that it will be useful to repeat before going further:

Epistemic character is a property of a technique. It structures the process of working things out whilst using the technique.

I use the verb "to structure" because it may apply to both the temporal and physical arrangement of the technique, and alludes to the structure of a cognitive ("working out") system. The three questions below are all intended to investigate how processes are structured, by bestowing techniques with "epistemic credit".

5.1. What are the Questions Posed by a Technique?

In the first of three questions to be asked of epistemic character, I suggest that we can try identify what the *questions posed by a technique* are, and how they influence the process of working things out.

5.1.1. Affordances and Conversations

Whilst I believe the idea of techniques posing questions to be a novel one, it is not without similar precedents. It is not unrelated, for example, to the notion of affordances. The noun "affordance" was introduced by ecological psychologist James Gibson, to describe features of the environment that provided possibilities for action (1979). In his appropriation of Gibson's work from a product design perspective, Donald Norman has presented affordances as an enlightening lens through which to think about product interaction, especially in the context of software design (1998; see also, Flach, Stappers and Voorhorst 2017; Baber 2003). Norman develops the idea of affordance by opposing it with the notion of 'constraints' (1998, p.82). Where affordances offer a range of possibilities, constraints set the limits on these possibilities. To borrow from Norman's example of Lego parts (ibid., see p.85), we can say that the bricks afford a variety of spacing and arrangement options, but these options are limited by the constraints of their alignment mechanism (the interlocking pegs and holes).

Although I acknowledge that techniques could be studied with reference to their affordances, I consider the idea of affordance to be too passive for my purposes. I regard Norman's coupling of affordances with constraints to be a means of redressing this underlying passivity. I suggest that the notion of techniques posing questions, rather than affording possibilities, promotes their more active role in the kinds of "actively extrenalised" cognitive systems described in Chapter 3 (see 3.2.3)[1].

The conversational metaphor I employ (of questions and answers) also has its precedents, perhaps most famously in Donald Schön's description of design practice as a conversation with materials (1983, 1994; see also Gedenryd 1998 for discussion of Schön's work). In addition, I have found the idea of the conversational character of techniques in Carole Link's PhD study, of cabinetmaking as a "dynamic system of decisions and interactions" (1975). And there is a similar theme underlying Andrew Pickering's 'dialectic of resistance and accommodation' (1995, p.39, as discussed in 3.2.4). It is these, more interactive approaches,

[1] I refer here to Clark and Chalmers' "active externalism" (1998).

which I hope to channel in the following comparison of rulers (Figure 5.1) and dividers (Figure 5.2).

Figure 5. 1 A six-inch ruler

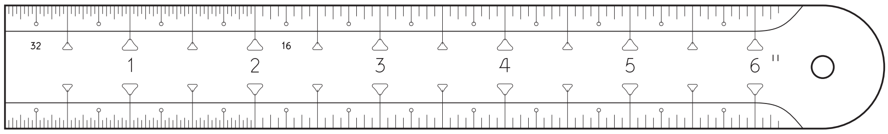
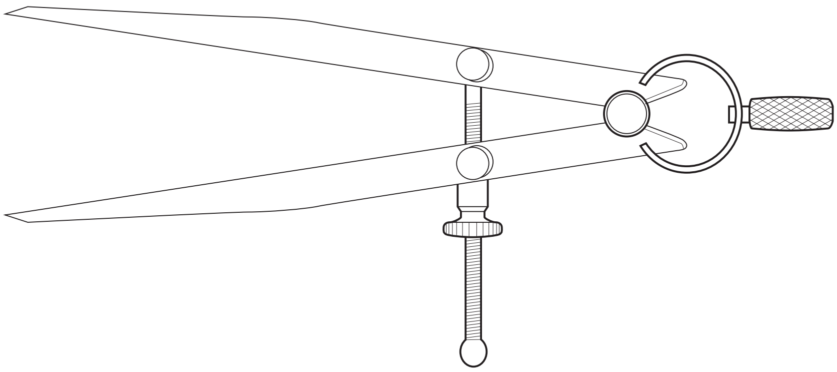


Figure 5. 2 A pair of dividers



5.1.2. Rulers and Dividers

Rulers and dividers enable the discovery and definition of distances. Both tools may be used as instruments with which to design, in order to determine the dimensions of a nascent artefact. Whilst similar in their capabilities however, there is a fundamental difference in the nature of the two tools. A ruler may be used to specify distances according to standardised systems of measurement (millimetres or inches, for example), whereas dividers are used to step out proportional relationships. In what follows, I compare these alternative techniques of layout, and consider how they ask us to conceive of an emergent design in very different terms.

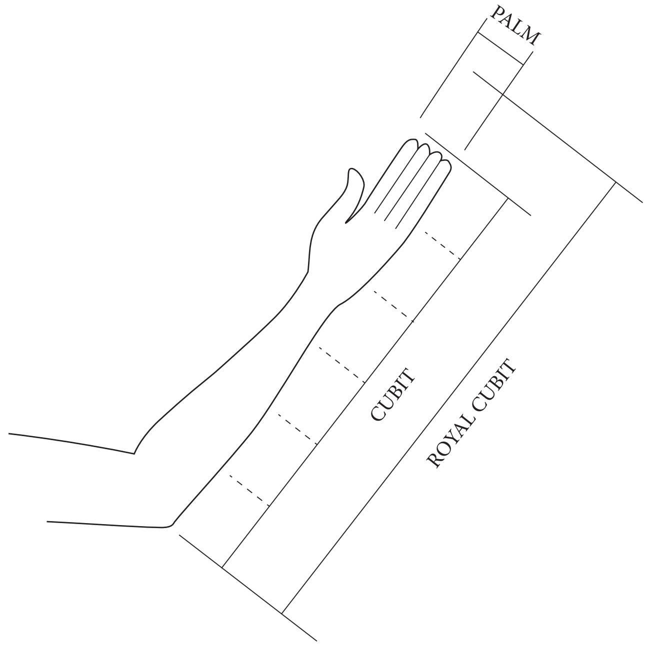
This is a comparison that first requires reflection on the role of measurement systems in design practice. I begin, therefore, with a brief history of these systems. I aim to clarify that, despite their ubiquity throughout contemporary practice, standardised units of measure are not a prerequisite of design work. I discuss pre-industrial methods of designing and making to both demonstrate this and, for those unfamiliar with divider use, introduce how proportional systems of layout work.

5.1.3. Systems of Measurement

The earliest known systems of measurement saw ancient builders lay out dimensions using distances found on their body. The convenience of having such measures (quite literally) to hand meant that distances like the cubit, which was the distance between the point of the elbow and the tip of the middle finger, were in widespread use across many cultures (Williams 2014, see p.1-6). Using dimensions defined by arms, feet, fingers and hands, the designers and makers of antiquity were able to develop, remember and share the information required to lay out their work. Variation inevitably existed between distances measured by different individuals, but these discrepancies were not considered problematic. Accuracy in the joints of woodworkers, masons or metalsmiths relied on their ability to fit one component to another according to the specifics of an individual circumstance, rather than precise adherence to a universal system of measurement (Turnbull 1993). In contrast to the contemporary scenario of distributed labour, production lines, and outsourced components, exact definitions of distance offered few advantages when parts were made to fit locally.

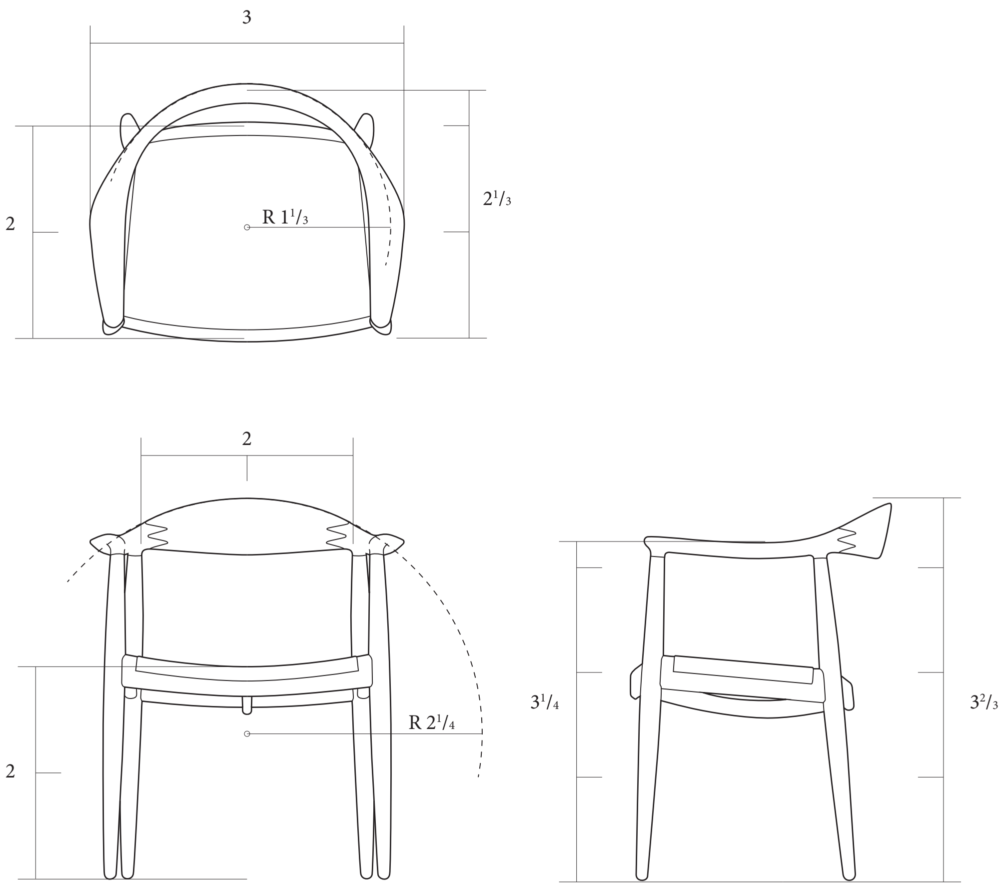
Beyond the convenience of being readily available on any job site, distances found on the human body also provided ancient builders with a collection of dimensions that had useful proportional relationships. For example, the cubit was divided into six palm widths (Figure 5.3). A measurement made using the thumb could be multiplied 12 times to approximate the length of a foot. The distance between the tip of the nose and the fingertips of an outstretched hand equalled three feet, and an arm span was twice this length (Williams 2014, see p.1-6). Again, although such distances would vary between individuals, these proportional relationships across the same person's body were usefully consistent. Using simple divisions and multiplications of these measures, artisans were able to discover structurally sound and beautiful proportions, as they designed and made artifacts of lasting appeal.

Figure 5. 3 An Egyptian cubit and its subdivisions of six palms



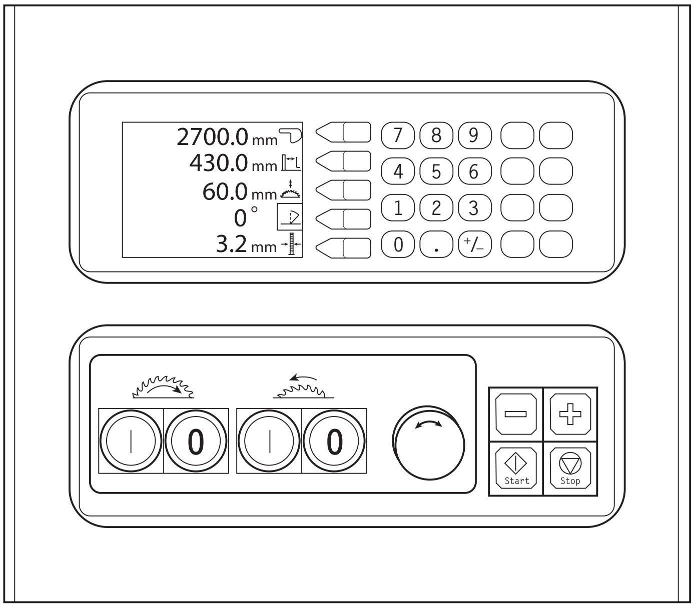
In their book, *By Hand & Eye*, woodwork instructors and theorists George Walker and Jim Tolpin refer to these methods of design and production as ‘artisan geometry’ (Walker & Tolpin 2013, p.97). Their investigation of the subject leads them to study the tools and techniques used by the artisans of what they call the ‘pre-industrial’ age (ibid.). With just a pair of dividers, a straightedge, string and a mark-making tool, and without any recourse to complex mathematics, Walker and Tolpin show how designers and makers were able to accurately lay out all the angles, curves and shapes they needed. Rather than being specified by standardized units of distance or degrees of angles, these designs were made with reference only to proportional relationships. Instead of asking, ‘How high is this base dimension in inches?’ when making a piece of furniture, pre-industrial artisans would have asked, ‘How tall is this base in proportion to the case above it? How wide is this leg in proportion to its height? How much does this leg taper in proportion to its width at the widest part?’ (ibid., p.11). Very often, the first dimension of a design was fixed according to the designer or maker’s own body. For example, a chair seat could typically be set to two hand spans high (ibid., p.165). With their dividers set to the width of a hand span, or simple whole number divisions of this dimension, designers could then determine the sizes of the chair’s other elements (Figure 5.4). In this mode of working, a system of measurement is developed alongside each design, unique to the demands of the task. Designing in this way focuses attention on the association of parts and wholes.

Figure 5. 4 "The Round One" Chair by Hans J. Wegner, with modules overlaid, where one module is roughly equivalent to a hand span



Only with the advent of industrialized production did shared units of measurement become valuable. When component parts began to be made in multiples, to be assembled later along a production line, their sizes needed to be closely controlled. Although we see some evidence of rudimentary standardization in pre-industrialized society (e.g. cubit rods made of wood or stone were used in ancient Egypt), the need for precisely defined, shared units of measurement grew only with the demands of mechanized production. Walker and Tolpin explain that 'as cutting tools were bolted to machine fixtures rather than guided by hands […] we began needing numbers to feed machines' (ibid., p.10). Figure 5.5 illustrates one example of this development, in a table saw interface.

Figure 5. 5 A table saw interface



My interest here is not to argue against the obvious usefulness of standardized measurement systems and the associated tools and techniques that use them. Conceiving of how modern production processes could work without shared measures is impossible. However, despite their contemporary ubiquity, the methods of pre-industrialized production demonstrate that standardized and precise units of measurement are not a prerequisite of design practice. As happened throughout antiquity, working without these units is certainly possible—until they are required to be fed into a machine or specified on a drawing for third-party production.

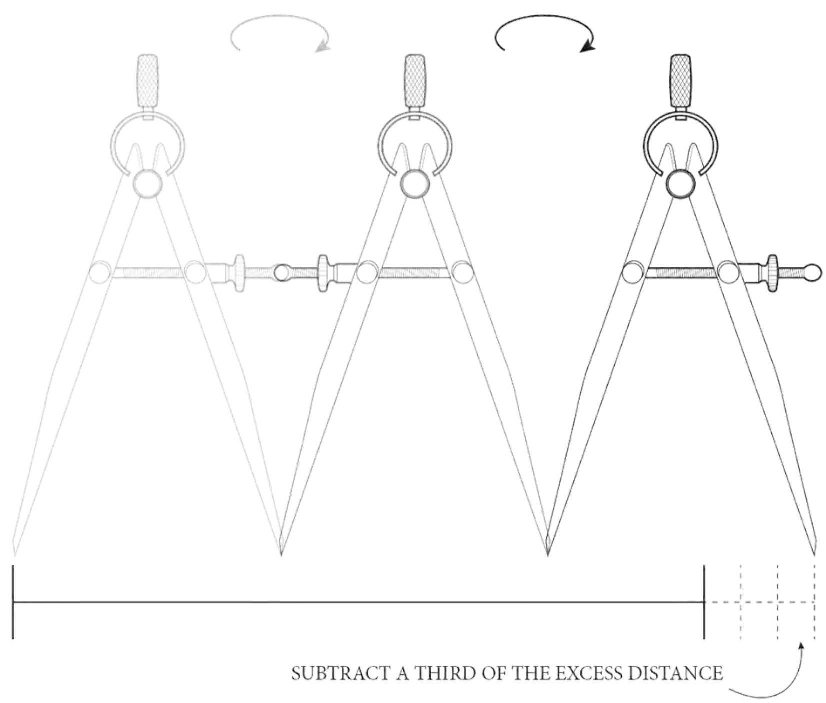
Throughout this discussion then, I do not present dividers and the associated use of proportional layout systems as a relic of bygone artisanal techniques. In many situations of design practice, they can be understood as an alternative to drawing freehand or using a ruler or any other method. In comparing the use of dividers and rulers, the topic of interest is not the limits of their capacities, or what they can and cannot be used for. I compare the tools not to suggest that they are interchangeable or of equivalent function, but as a means to explore how these alternative methods of discovering and defining distances structure the process of design.

5.1.4. Using Rulers and Dividers

Rulers and dividers are multi-purpose tools. Generally, they can be used in one of two ways: to discover the dimensions or proportions of existing things or to help lay out designs on a surface. Very often, a task requires rulers or dividers to be used in each of these modes—both as instruments of discovery and as tools for marking new features. Here, I describe a simple task that combines these two purposes to illustrate a fundamental difference between the tools.

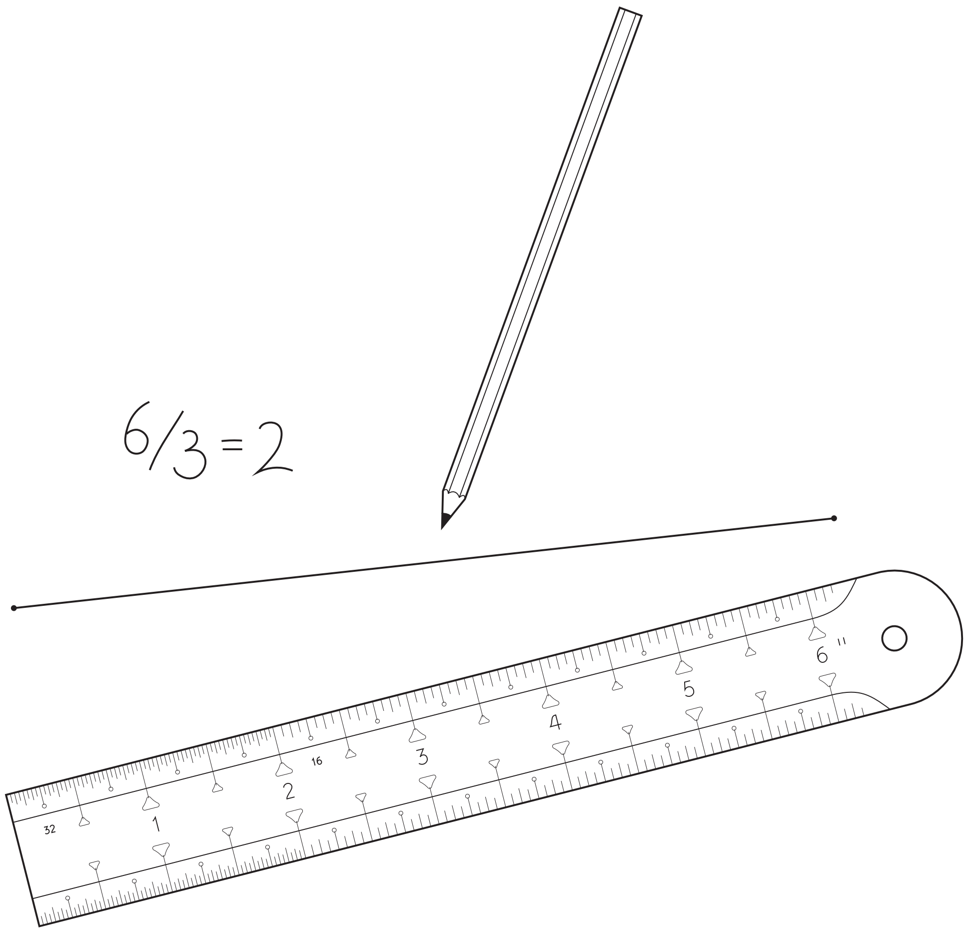
Imagine we would like to divide a line into thirds along its length. Using dividers, the first task is to approximate a third of the distance and set the points of the tool to this dimension. The distance can then be "stepped out" to check the approximation. Any inaccuracy in this first attempt can be revealed by "walking" the dividers from one end of the line toward the other. If the final step under- or overshoots the endpoint of the line, a third of this dimension should be added or removed, respectively (Figure 5.6). With practice, designers might achieve a successful division into thirds on this second attempt. If not, they can repeat the process until the even thirds are discovered. After the dividers are correctly set, they can be used to mark the divisions into a substrate's surface, by applying more pressure to the points throughout another series of steps.

Figure 5. 6 Dividing a line with dividers



Performing the same task with a ruler, we would first measure the length of the line. This numerical dimension can then be divided by three (Figure 5.7). The calculation can be done mentally, on paper or using a calculator. The resulting dimensions of the thirds are then marked using a pen, pencil or knife alongside the ruler's edge.

Figure 5. 7 Dividing a line with a ruler



Using either the ruler or the dividers, an identical result can be achieved: the line can be accurately divided into three lengths. This exercise, then, does not expose the varying capacities of these two layout tools, nor is it an instance of using them in search of an as-yet-undetermined form. However, even this simple task introduces an important difference in the nature of these tools and their associated techniques. This difference lies in the ruler's numerical system of measurement and the dividers' proportional system. A ruler always must refer to the units of a standardized measurement system, where a pair of dividers attends to the relationships of physical, real world distances.

5.1.5. Using Dividers to Design: Questions of Proportion

In the example of dividing a line, we see that the questions that might be resolved using a pair of dividers involve the relationships between different elements. In other words, we might say that dividers pose questions in terms of proportional relationships. This phrasing takes seriously the role that tools and techniques play as extensions of minds. Dividers structure action around the discovery and creation of proportional relationships. Moving on from dividing a line into thirds, this aspect of their character is most apparent if we consider the sequence in which they are used to design previously unspecified forms.

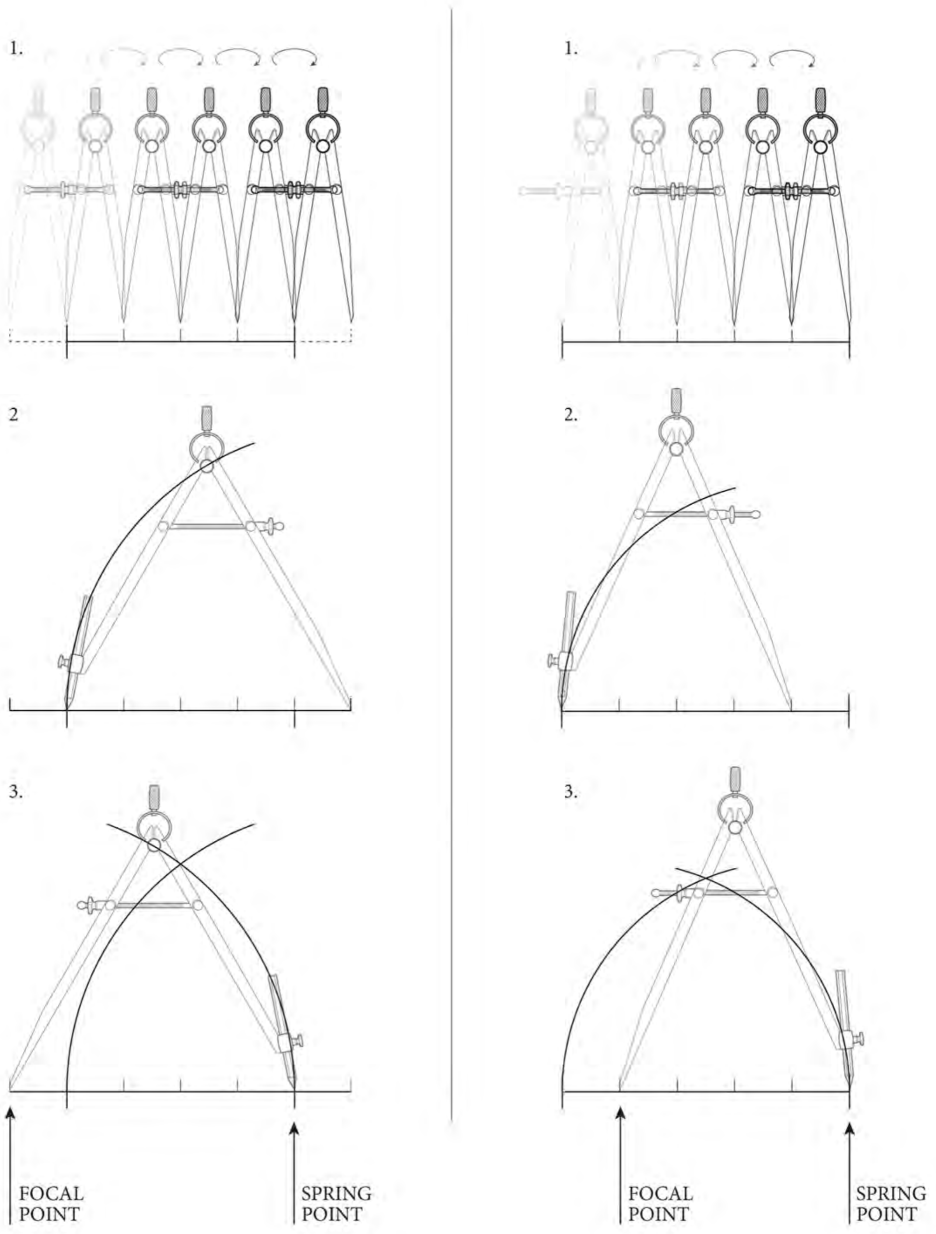
Before dividers are used to mark any point, they first must be set to a particular distance. This distance should be one that is useful in creating the lines and shapes of a design. If it is too large, it does not allow us to mark the smaller dimensions of a design. If it is too small, stepping out long distances becomes unnecessarily laborious. This first task thus introduces a critical concern during the use of dividers: the length of the "module." A module is a distance that can be divided or multiplied repeatedly to create the lines and shapes of a design (see Figure 5.4) (Walker and Tolpin 2013, see p.153).

The module need not be specified in millimeters or inches; designing in this way defines the relationship between elements rather than their absolute dimensions. Unless we aim to create a layout that is the actual size of the finished artifact, the precise distance to which the dividers are set while designing is not critical. Any design created using a module-based approach can be easily scaled up or down at a later stage, by adjusting the actual dimension to which the module is equivalent. Thus, as we design a specific instance of an artifact, we are also creating what might be termed a generative sequence that can be followed to create the same artifact at differing sizes[2]. The scalability of divider-made designs was an advantage exploited by the designers and makers of the past. For example, when laying out a pointed arch, alternative sequences can be used to step out the spring and focal points to create arches that have different qualities (see Figure 5.8)[3]. That such sequences can be easily remembered, shared, and adapted to the particulars of individual circumstances made them highly valuable to the builders of antiquity (Turnbull 1993, see p.323).

[2] For a discussion of how generative sequences can be employed throughout processes of designing and making, see Christopher Alexander (2002, p.301-2)

[3] Example taken from George R. Walker and Jim Tolpin (2015, p.117)

Figure 5. 8 How to draw a slender arch (left, with focal points outside the spring points) and how to draw a broader arch (right, with focal points inside the spring points)



As a more contemporary example, using a pair of dividers in the practice of designing a chair (e.g., the one in Figure 5.4) requires us to continually reconsider the relationship of the module to the whole design as we work. Does this distance allow us to create the right kinds of proportions? Are the divisions simple to work with? For example, divisions of 12 (e.g., one-sixth, one-fourth, one-third, and one-half), like those found in the body part measurements of antiquity, offer more whole number fraction options than when using divisions of 10 (with just one-fifth and one-half). Thus, right at the beginning of our design process, setting and resetting the dividers becomes a key concern, as we continually reconsider the relationship between parts, as well as the appropriateness of the module and its divisions for the task. Frequent revision of this setting is often necessary, until a useful module emerges alongside the design work. As designers experiment with the tool, by tentatively stepping out the potential relationships, both the artifact and its own unique system of measurement begin to emerge.

5.1.6. Using a ruler to design: Questions of Units

When using a ruler to determine the distance between points, we begin by placing it on a surface so that it spans the two (or more) points we would like to define. Once one of the points has been marked, a ruler allows us to decide on the location of the other points by referring to the markings of a measurement system that run along its edge. These graduated markings are continuous, enabling us to choose any dimension that seems appropriate. Once the first set of points has been marked, the ruler is moved to span the next distance, and we again are required to decide on the dimension.

To again take the extended mind argument seriously, and to consider tools to be an important part of cognitive systems, we might say that the ruler poses questions in terms of universal units of measure. Each time the ruler is repositioned, it physically retains no information about the previous decisions made, and we are free to choose any dimension along the continuous scale. Unlike setting and resetting a pair of dividers, the sequence of steps when using a ruler does not ask us to consider proportional relationships from the start. Instead, it allows us to define any feature of a design independently from the others; it allows, and even encourages, a dramatic shift in attention away from the proportional concerns prompted by a pair of dividers.

Of course, making a design with the same proportional relationships using either a pair of dividers or a ruler would be possible. Indeed, if we disregard the importance of the external world in the process, we might argue that these decisions are always a matter for the internal cognitive capacities of the designer, regardless of what tools and techniques they are using. However, what is clear from the examination here is that a ruler does not structure the task in terms of proportion. We do not need to start by discovering a useful module, and we do not need to step off an emergent design to quickly determine proportional relationships. Any such relationships may be discovered only upon reflection, with reference to the units of measure and through the detour of mathematics.

5.1.7. Summary of Rulers and Dividers

My study of rulers and dividers has aimed to uncover how these tools and their techniques structure processes of design differently, by prioritizing certain qualities over others. The evidence for these differences can be found in the physical and temporal arrangement of the techniques. A ruler is placed on a surface, allowing us to run or jump a pen, pencil, or knife between any of its gradated markings. A line's start and end points must be linked by the tool before the line is drawn, or the marks are made. A pair of dividers walks across a surface, meaning that we cannot leap-frog from one point to another, but must arrive at an end point only having taken and considered each step according to the proportional system of measurement. In the analysis given here, I have framed this difference by focusing on the questions posed by the tools. The techniques of divider use require that we consider questions of proportion, and those of ruler use ask us to determine distances in the shared units of a measuring system.

Throughout this study, I have tried to give a sober account of the differences between divider and ruler techniques, leaving to the reader decisions about the merits of designing while using different systems of measurement. Indeed, the real value of this kind of technology (to borrow Siguat's phrase, see 5.6.3) is that it helps each of us to better identify the relationship between the techniques of design practice and the outcomes, and then to align them accordingly. From a historical perspective, this link between the tools of design and the resulting forms created is clearly seen. Dividers are emblematic of a time in which the study and creation of proportional relationships dominated scientific and artistic thought.[4]

In contemporary design practice, proportions are usually given less consideration. Dividers are not as ubiquitous as they once were—and neither are rulers, for that matter, as computer-aided design (CAD) software has taken an increasingly dominant role in much design development. On this point, we might consider the techniques associated with CAD. In most cases, as the first line is drawn in CAD software, the user is immediately asked how long that line should be, in either millimeters or inches (see figure CAD). Subsequent lines also are to be specified in these units because each element of a drawing can be considered

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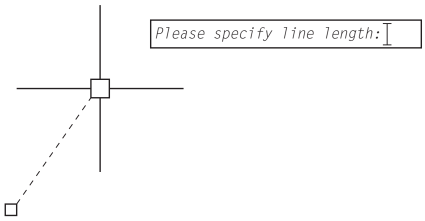
[4] Such emphasis is clearly expressed, for example, in Luca Pacioli's 1509 book *De divina proportione (The Divine Proportion)*, which, inspired by the ancient ideas of Vitruvius, cites proportion as the most important architectural concept—see Kruft (1994, p.63). See also Walker and Tolpin, (2013, p.9-10).

without relation to those that have been created before[5]. In ruler-like fashion, then, the universal measurements required of modern manufacturing appear to have been transmitted from the tools and techniques of factories into the tools and techniques of design studios. We now feed numbers into the machines that sit on our desks.

Figure 5. 9 CAD interface asking for the dimensions of a line



As we examine the techniques associated with design tools like rulers, dividers, and CAD software, I suggest the usefulness of extended mind theory starts to become apparent. Without this perspective, we instead rely on what Gedenryd calls "intramental" (1998, p.7) accounts of cognition and infer that tools are mediators used to transcribe pre-existing ideas into reality. In this model, we are limited to discussing only the degrees of certainty with which our tools can achieve a prescribed result. However, by undertaking the kind of analysis demonstrated in the divider/ruler comparison, and by granting things the epistemic credit they deserve, designers can better see and discuss how tools and techniques influence processes of design, prioritizing some decisions over others and emphasizing certain qualities. I suggest the idea of techniques posing questions to be a useful metaphor with which to investigate this issue. This is a subject I return to in the next chapter.

5.2. What is the Step-Character of a Technique?

In the second of three questions that may be asked of epistemic character, I introduce the idea of *step-character*. This is perhaps the most significant question we may ask of a technique's epistemic character, as it structures the distribution of occasions for questions to

[5] To avoid falling into a trap discouraged by Sigaut (of using technological analyses without a proper understanding of techniques, see 2.6.4), I would note that designing parametrically in CAD software does create relationships between parts and wholes.

be asked (5.1), and the opportunities for emergent results to provide feedback (5.3). It therefore has a significant effect on the other two questions.

Once I have discussed the theoretical influences on the idea of step-character, I demonstrate how we may pursue the question with reference to the techniques used in carving a wooden spoon.

5.2.1. What is a 'step' of production?

Understanding production as a step-by-step process is common across disciplines interested in designing and making (see, for example, the *chaine opertoire* or operational sequence in archaeology, 2.6.11). Despite this widespread use, however, it will be helpful to offer a clarification of what I mean by a *step*. I am using the phrase conventionally, to describe an incremental movement from one state to another. But there is an important point to be made in relation to how the steps of production may be delineated. Consider, for example, the action of sawing a board of timber as a step of production. In the sequence, 1. *measure alcove, 2. saw timber, 3. screw shelf brackets to wall, 4. screw timber to shelf brackets*, the step "saw timber" makes sense. We could, however, just as logically divide individual saw strokes into steps or, in the opposite direction, understand the fitting of a shelf as one step, before the subsequent steps of building the surrounding cupboard or painting can take place. In analyses of making practice, therefore, the steps of production may be defined arbitrarily. According to what suits the particular discussion, we could regard any part of a process as a single step.

Throughout this section, I divide making techniques into finer delineations than is typical. Whilst we might often think of longer instances of tool use (i.e. hammering in a nail or chiselling a mortise) as the discrete steps of an operational sequence, I wish to emphasise that such actions are in fact made up of lots of smaller steps. This is in accord with Tim Ingold, who presents a study of sawing a board of timber in an effort to discuss the nature of tool use (2011, see p.51-62). Ingold takes an approach that divides the operation of sawing into multiple steps. Through a detailed description of the various phases of sawing, Ingold argues that to compress the subtle variations of technique and the adjustments that take place into one single step—*saw the board—*is to miss the journey-like nature of tool use. Rather than 'leap-frogging the world' (ibid., p.152) from one state of relative completion to another, Ingold claims that making practices progress by way of a 'journey that proceeds from place to place' (ibid., p.53) - 'cutting a plank is more a walk than a step' (ibid., p.57). Whilst the smaller, proximate steps Ingold describes (like nicking the edge of the board to start a cut, or changing from one rhythm of sawing to another) might appear to flow into one another without any noticeable divisions, subsuming these steps into one longer step reinforces the hylomorphic assumption that 'each stage in the process of making an artefact is completed at the point when the material outcome precisely matches the maker's initial intention' (ibid., p.55). For Ingold, collapsing making processes into longer operational steps like "saw timber" precludes any consideration of the adjustments and corrections that take place throughout such processes (this is an idea that corresponds with Fracois Sigaut's discussion of technological studies, see 2.6.3).

How we define the steps of a productive technique thus betrays assumptions made about the significance of that technique. The level of detail of a study is intertwined with its aims and theoretical foundation. Based upon the emergent understanding of production described in Chapter 3, and the epistemic nature of tool use described in the previous chapter, the position I take is that the small, incremental steps of a technique have a significant bearing on its epistemic character and are worthy of attention.

The discussion of step-character presented here thus requires a fine-grained analysis of tools and techniques (see Malafouris 2013; see 2.6.12 on chrono-architectures). At this scale, the delineation of steps becomes enmeshed with the physical arrangement of tools, materials and the practitioner. Ingold's analysis considers an individual saw stroke to constitute a "step". Keller and Keller take a 'heat' as a unit of action in blacksmithing (1996, p.108). In the previous chapter, the analysis of hammer use was interested in each blow as a step. If we were to use a hand plane to thickness the sawn board, we could understand each pass of the plane as a step—with each shaving ejected from the plane's mouth becoming the evidence of that step. And the steps of divider use, or the marks made alongside a ruler described above are taken to be steps of those techniques. Whilst I acknowledge that the steps of production may be defined arbitrarily in post hoc analyses then, this chapter finds steps such as these to be well-defined features of practice. I suggest that the steps of a process are defined, or punctuated, by opportunities for reflection and revision. These opportunities are, to borrow from Carol Link's terminology (and also Donald Schön 1983, see p.78-9), the pauses in conversation between a practitioner and their material. In the study below, it is these kinds of steps—those small incremental advances that present themselves throughout practice—which I will be describing.

5.2.2. Carving a Spoon

Before discussing the step-character of the techniques involved in carving a spoon, it is important to define the emergent nature of the process. In the discussion of rulers and dividers, I described only the general nature of how such tools might be used to layout a design. Because they are often used to create drawings, it is perhaps easier to understand rulers and dividers as tools of design practice. They can be readily understood as for "working things out". As seen in the spoon example, however, I suggest we do not have to limit studies of epistemic character only to those techniques that create drawings. In the context of workshop practice, I suggest that all tools and techniques can be understood as means by which to work things out.

With this development, however, comes a potential difficulty. Where in the case of ruler and divider use it might have been possible to suspend the usual assumption that a practitioner is realizing an idea that already exists in their head, this comes less naturally in the case of non-typical design tools. The experience of using a ruler to determine the dimension of an as-yet-imaginary object is quite common, even in an everyday context (when, for example, baking a cake). The experience of using a saw, axe or knife to work out the shape of a piece of wood is far less common. We are perhaps much more inclined to interpret such techniques in accordance with the linear model of thought and action criticised in Chapter 3 (see 3.2).

I believe the example of spoon-carving can help in this regard. Owing to the fibrous nature of wood, and the technical choices (of tools) I have made for this study, the outcome of the process is conspicuously emergent. In the phraseology of John Protevi, we must follow an artisanal approach (2001; see 3.3.1). But this itself raises a problem—how is this discussion, founded in a highly artisanal context, more broadly applicable? I would answer by reiterating the commitment made in Chapter 3, to a fundamentally emergent understanding of production, and the idea that design is always a plan-*making* activity (see 3.4). Whilst the wooden spoon completed throughout the process below is a "finished product", the process of its production is analogous to the creation of any three-dimensional prototype, where the design and its realization emerge simultaneously. And the underlying concept, the question of a technique's step-character, may be asked of any technique.

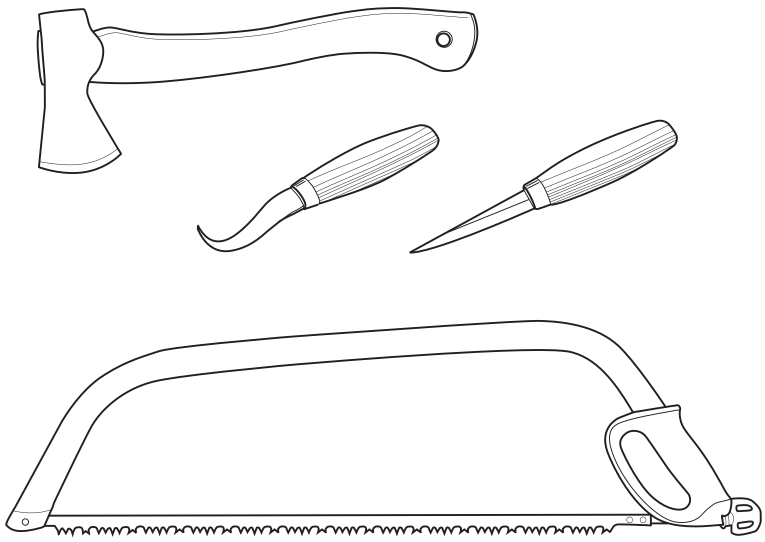
In addition to its conspicuously emergent nature, I have also chosen the example of spoon carving for the following reasons;

- It incorporates various tools and techniques, which have different step-characters, and therefore allows us to make convenient comparisons
- It allows us to explore the relationship between techniques and the material being worked, and demonstrates that step-character is a result of this relationship (see, for instance, the differences in step-character when splitting or shaving wood using the same tool—an axe; see also 6.2.2)

- The process has been well-documented by others, providing reliable sources from which to justify my description

The process of carving a spoon I describe below involves a small collection of tools and three methods of wasting wood—sawing, splitting and shaving. Although there are many technical choices available to the woodworker interested in spoon making, here I describe a typical process, which employs a saw, an axe, a knife and a hook knife (Figure 5.10).

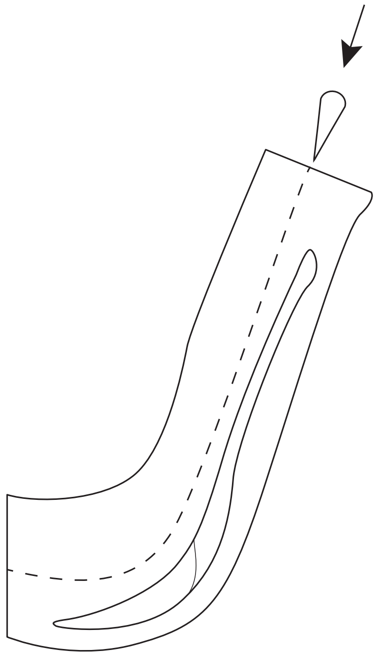
Figure 5. 10 An axe, bow saw, straight knife and hook knife



This way of working is common in green woodwork (Sundqvist 1990), where the high moisture content of the wood allows these tools to cut and split easily[6]. The advantage of using greenwood and the axe, and the reason this process is popular with woodworkers, is that splitting spoon blanks (the piece of wood from which a spoon is to be carved) ensures that the spoon follows the curve of the grain (Figure 5.11).

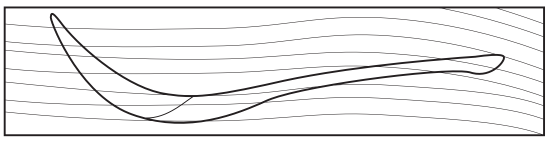
[6] Were a spoon to be made using dried timber, however, carving with an axe as described below would be difficult and likely replaced with coping or band saw cuts.

Figure 5. 11 Spoon following curvature of grain. The dotted line represents where the log will be split



With careful material selection, this enables a practitioner to create spoon forms with a greater curvature, without sacrificing strength. If the same parts were to be made from a straight-grained piece of timber (or sawn indiscriminately from any piece of timber) it would result in a spoon with grain 'run-out' (Figure 5.12, after Sundqvist's: ibid., p.101) that is more likely to snap under stress.

Figure 5. 12 A spoon that doesn't follow the grain



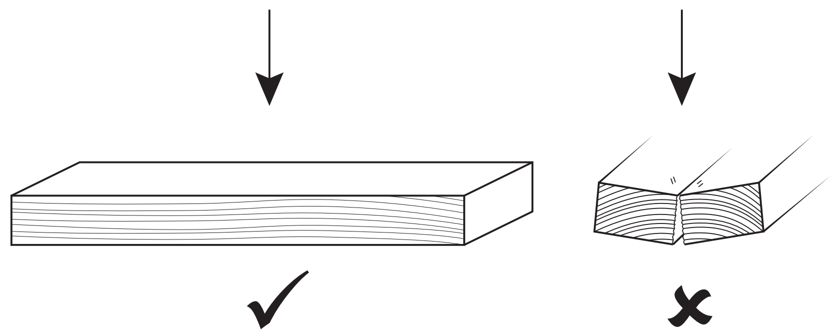
5.2.3. Ways of Wasting Wood & Working with Grain

The three techniques of wasting wood in the example below—using a saw, axe and knife—each illustrate a different step-character. Before describing the techniques in more detail, it will be helpful to explain how each method of wasting wood interacts with the material.

The techniques associated with saws, axes and knives have been developed to account for the behaviour of wood as a fibrous material. In order to consider these techniques in any detail, it is first necessary to understand this fibrous nature. A useful analogy offered by woodwork writer Jeff Miller is to think of pieces of timber as composed of bundles of loosely connected straws (2012, p.12). The straws represent the fibres of a tree. When it is still standing, the straws transport water and sugars up and down the tree. Once harvested as timber, the straws become the grain of our piece of wood.

Miller's loose bundle of straws analogy is relevant here because it illustrates a key property of wood—individual wood fibres are stronger than the bonds between them. Whilst the straws themselves can break, the connections between them break much more readily. For those designing structures to be made from timber, it is this property of the material that is exploited when aligning the grain along a part's length, to maximize strength (Figure 5.13).

Figure 5. 13 Aligning parts to the grain direction

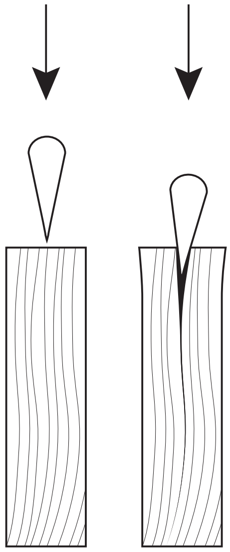


For the present discussion of using a saw, axe or knife, the bundle of straws model helps to explain how wood fibres behave when subjected to these techniques. The actions mediated by these tools can be placed into three categories—splitting, shaving and sawing, each of which is employed in the following example of spoon carving.

<u>Splitting Wood</u>

A piece of wood is split by driving a wedge into its end grain (the ends of the fibres) (Figure 5.14).

Figure 5. 14 Splitting wood



Owing to the weaker bonds between wood fibres, the wedge splits the piece of wood along these bonds. The split line thus follows the line of the fibres, resulting in split parts whose surfaces are rarely flat, and instead take on whatever curvature is in the grain.

Shaving Wood

When a piece of wood is shaved, a blade slices through its fibres. The wasted wood is removed as shavings, as in the continuous peeling often ejected from the throat of a bench plane. The angle at which the blade meets the fibres is a matter of concern for the woodworker, who will usually aim to shave with the grain. Figures 5.15 and 5.16 show how the direction of travel of a blade can be altered between shaving with the grain, or against the grain, respectively.

Figure 5. 15 Shaving with the grain

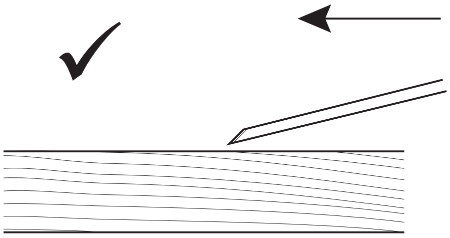
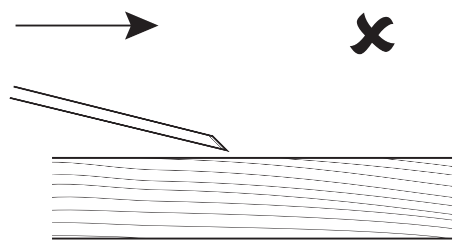


Figure 5. 16 Shaving against the grain



When shaving as in Figure 5.15, the blade slices through the fibres, leaving a smooth surface. When the direction is reversed, as in Figure 5.16, the blade hits the ends of the wood fibres and, rather than slicing through them, instead begins to split them apart. Once the split fibres curl back over on themselves, they usually snap off, leaving a rough, uneven surface. When planing a surface in an effort to make it smooth, this undesirable result is known as tear-out. Apart from in this instance, shaving does not follow the paths of fibres.

<u>Sawing Wood</u>

There are two types of saw cut when working with wood; rip cuts and cross cuts. Rip cuts are those made into end grain. The teeth of a saw making a rip cut act like a row of tiny chisels, breaking off the ends of fibres. Cross cuts are those made across the grain, as when sawing a board of timber to length (Sellers 2016, see p.321). Here the saw teeth cut through the fibres perpendicularly. Unlike pieces of wood that have been split, sawn parts typically have flat faces that do not follow the run of the grain. Saws cut through, rather than follow, the lines of fibres. This leaves surfaces patterned with the severed ends and beginnings of fiber lines that once ran through a larger piece of wood. It is these severed fiber lines that contribute to the grain patterns commonly found on the surfaces of furniture.

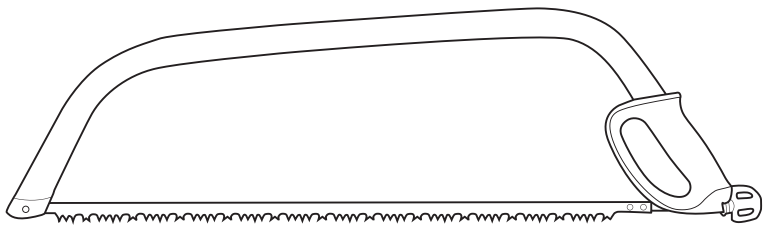
5.2.4. The Steps of Wasting Wood

In the following description of carving a spoon, I examine the epistemic character of saw, axe and knife techniques. Specifically, I want to consider the step-by-step nature of their progress. As described above, I have chosen these three tools for wasting wood because their associated techniques illustrate a variety of different step-characters.

<u>Part 1: Sawing a log to length</u>

Before splitting a log, it must be cut to length. Although it is possible to cut across the grain using an axe (as when felling a tree), the cuts can be made more cleanly (wasting less timber either side) by using a saw. When working with greenwood, it is helpful to use a bow saw with a blade specially adapted for cutting timber with a high moisture content (Figure 5.17).

Figure 5. 17 A bow saw



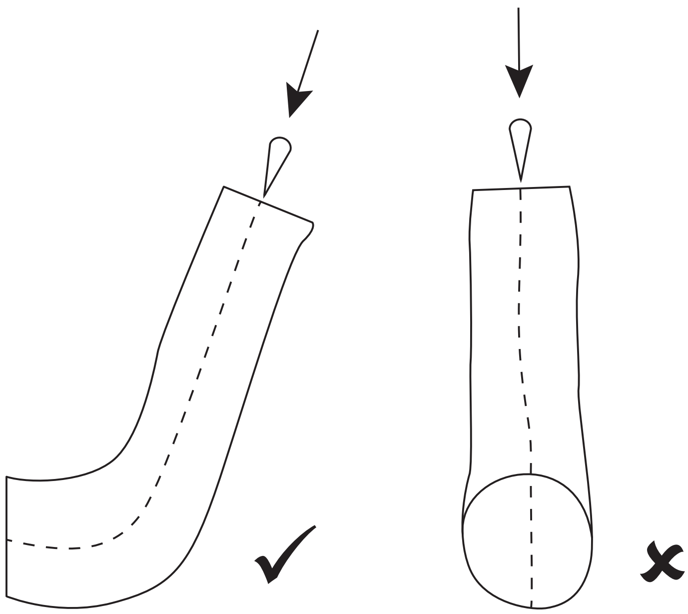
Unlike the precision required when, for example, sawing the tenon of a mortise and tenon joint, the cuts we make to size the spoon blank are not dimensionally critical. The exact length does not matter at this stage—so long as the blank is slightly longer than we need, excess can easily be removed later on. Despite different saw cuts requiring different levels of precision, however, the main feature of sawing's step-character is widely applicable across sawing operations—sawing generally lacks an emergent result that may be assessed and revised. Although the strokes of hand saw use have a rhythmic and incremental advance, the result of these strokes is revealed only at the end of the cut, when the waste is removed in one piece. The moment before starting a saw cut is thus one in which there must be certainty about its anticipated path. As the saying goes, *measure twice, cut once*.

Despite the generous tolerance for precision when cutting a spoon blank to length, the moment before cutting still demands we address the same question—"is this cut in the right place?". As part of the effort to exploit the shapes inherent in the grain of the wood, the section proposed to be cut should be carefully assessed. The shape should suit the eventual spoon type (Sundqvist 1990, see p.100). The resultant ends of the log should be close enough to parallel, so that it can stand up when being split. Any features (such as the traces of branches) identified on the bark, which might pose complications later in the process, should be identified and, if necessary, avoided. Whilst we might not be *measuring* twice before the saw cuts here, we are nonetheless required to decide upon an action that, once begun, will not give much opportunity for revision or alteration. Sawing thus has a step-character where decisions are made in advance, rather than distributed throughout the process (this is idea, the distribution of decision making is the theme of the next chapter).

<u>Part 2: Splitting Out the Blank</u>

Once sawn to length, the log needs to be split. Because the pith of the wood is unsuitable for use in a spoon, the log is usually split through this point. This allows the pith to be easily removed after splitting. The angle of the split across the end grain is chosen with reference to any curve in the log that would be useful for a spoon blank (Figure 5.18). Once this angle is determined, there are three potential techniques for driving the axe through it. All three require the log to be stood on end on a hard surface, usually a chopping block.

Figure 5. 18 How to orientate the split for a spoon



The first technique is to swing the axe at speed. This is the riskiest (and most impressive) of the three options, as it places demands on accuracy that can be hard to achieve. A more certain option is to rest the edge of the axe on the intended split line and, using the non-axe-wielding hand to lift the log, raising the axe and log simultaneously, before swiftly throwing them back down onto the chopping block. Because the axe edge remains in place throughout, the accuracy of the split is more easily controlled using this technique. The third method requires a mallet. Here, the axe head is first placed as in the second technique and then stuck with a mallet, driving it into the end grain. Again, this technique reduces the risk of the split starting in an unintended position.

Considering the step-character of the splitting technique, the most important feature of all the above strategies is that, once the axe starts to split apart wood fibres, the path of the whole split is immediately determined. As soon as a split has begun to travel down through the log, there is nothing that can be done to affect its course. Although a very different context to the factory machines that epitomise David Pye's workmanship of certainty (see

4.1.3), the process of splitting wood is similarly predetermined. The determining system at play in this case, however, rather than being carefully managed by machine operators, is intrinsic to the piece of wood and unknowable until the split has been made. This gives the technique of splitting a log a step-character that, like sawing, sees decisions made in advance of the action, rather than throughout.

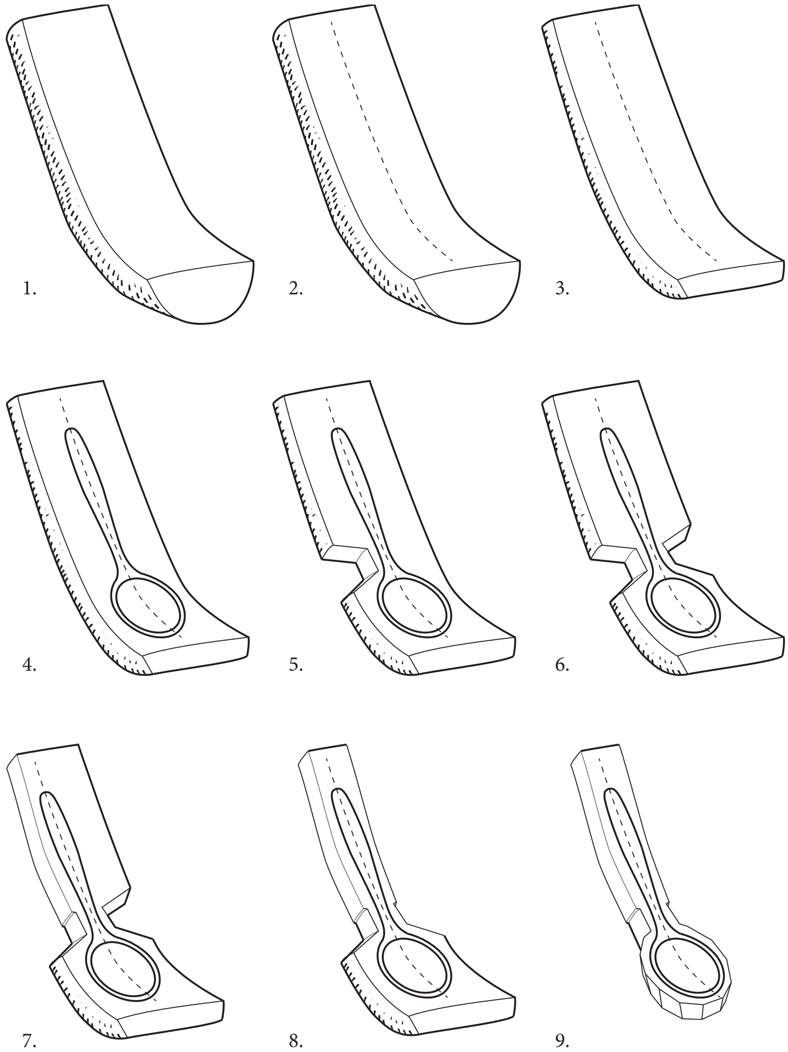
Part 3: Shaping with the Axe

Having split the log in two, the parts can be assessed for their suitability and work can begin to rough out the spoon shape with an axe. It is often possible to utilize both halves of the split log for spoon making (Sundqvist 1990, see p.101), in which case one might be temporarily stored in such a way as to minimize its moisture loss—from the moment of splitting, the pieces of wood start to dry, making carving more challenging. The process of shaping the spoon blank, therefore, normally follows soon after splitting.

In comparison to sawing or splitting the log, the process of shaping with the axe involves episodes of action during which finer-grained decision making takes place. Decisions are made throughout, in response to the emergent result. During this phase of the process, the axe is used in two modes—both as a tool for splitting the wood, as before, but also as a tool for shaving (to slice through wood fibres). Although the shavings made by an axe are rarely of the wispy or curly variety as ejected by handplanes, the principle of how the blade is cutting, as described above, still holds true.

Different practitioners are likely to use different sequences of action when shaping with an axe, and these sequences may be further adapted to the requirements of a particular spoon type, or a particularly characterful piece of wood. The universal validity of the sequence illustrated in Figure 5.19, however, is not of consequence. Similar sequences to the one shown have been documented by a variety of sources (for example, Sundqvist 1990, see p.101-123) and used by myself but, were the sequence to be reordered somehow, the discussion of the step-character of the techniques here would remain valid.

Figure 5. 19 Sequence of shaping a spoon blank, using an axe

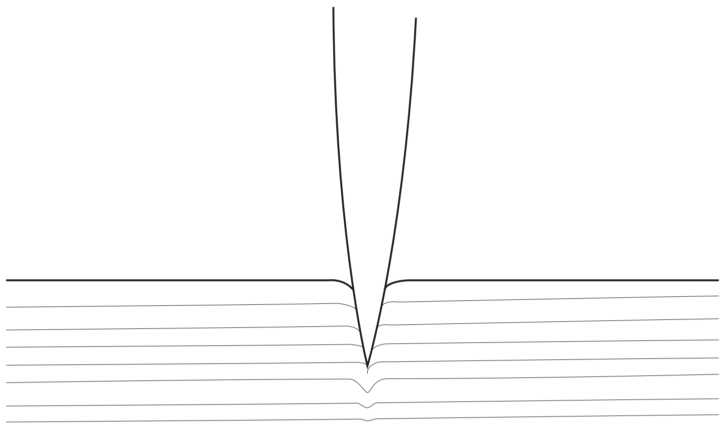


The stages of Figure 5.19 that are most useful for the discussion of step-character are: *5* and *6*, where cross-grain cuts are made to determine the point at which the bowl joins the handle; and *7* and *8*, which show how splits are made down to these cross-grain cuts to thin the handle. I will use these stages to illustrate how multi-step processes can be used to work things out in response to an emergent form.

Establishing the Bowl and Handle

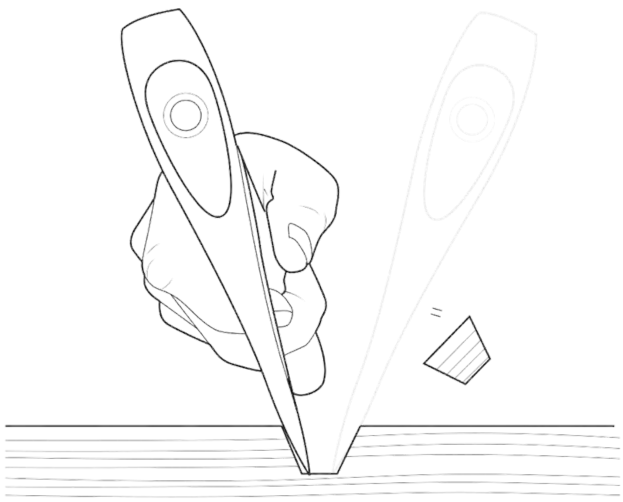
An axe that strikes at right angles to wood fibres can only travel a limited distance. Where a crosscutting saw removes wasted wood as saw dust, an axe can only sever and compress, not remove, the fibres. As they are compressed by the faces of the axe head, the fibres soon halt its progress (Figure 5.20).

Figure 5. 20 An axe edge compressing wood fibres



Because of this, axe blows are usually delivered at alternating angles, so that they can simultaneously sever and split out waste wood (Figure 5.21).

Figure 5. 21 Alternating axe blows



It is these kinds of cuts that are used to establish the form seen in stages *5* and *6* of Figure 5.19, where chops are made to determine the size and position of the spoon's neck (the joint of the bowl and handle). It would be rare for just two alternating axe blows to be used to make these neck cuts. Usually, the depth and position of the neck must be determined through a series of chops. The first stage is to remove wood until the correct depth is reached on both sides. This leaves a result (Figure 5.22) that offers a good opportunity for reflection, where the relative proportion of the bowl to handle becomes visible, and the position of the neck can be moved to alter this important characteristic of the spoon.

Figure 5. 22 Starting to define the neck

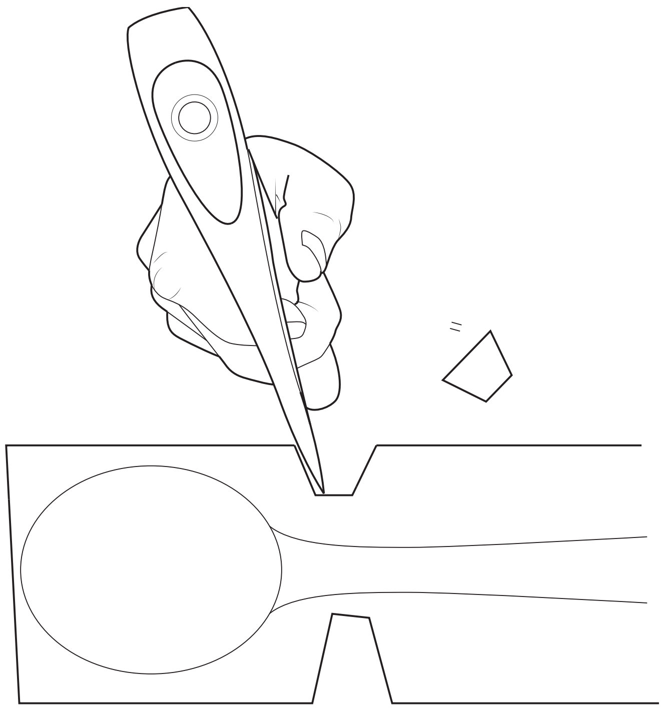
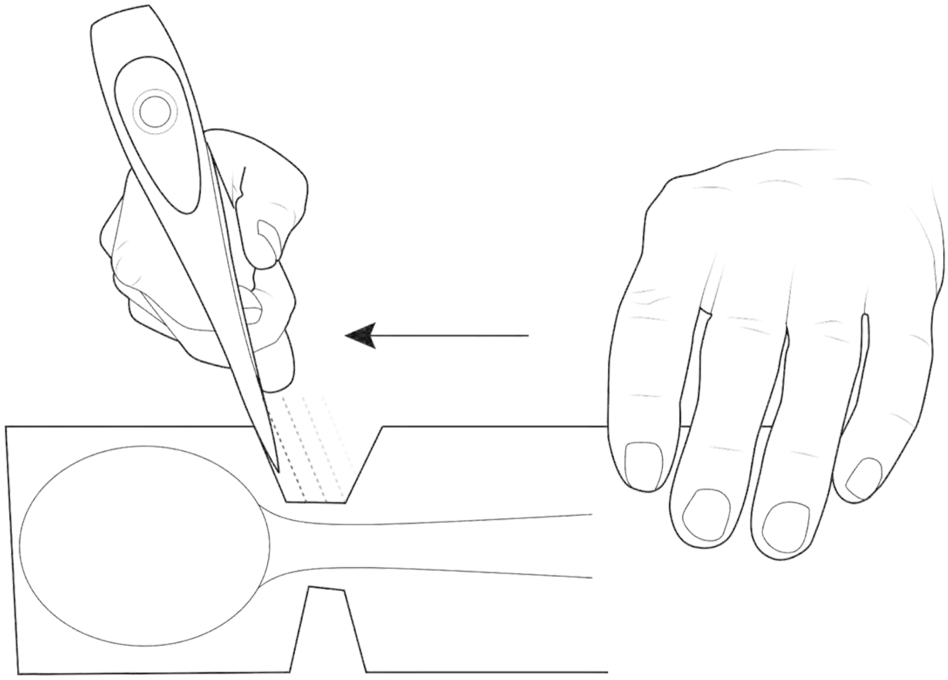


Figure 5.23 shows how further cuts can be used to move the neck closer to the bowl. Because adjustments can be made in this direction, it is advantageous to make the first cuts into the neck a little further up the handle than might be necessary, thereby avoiding making the bowl too small before assessing its size with the benefit of an emergent result.

Figure 5. 23 Adjusting the proportion of bowl to handle

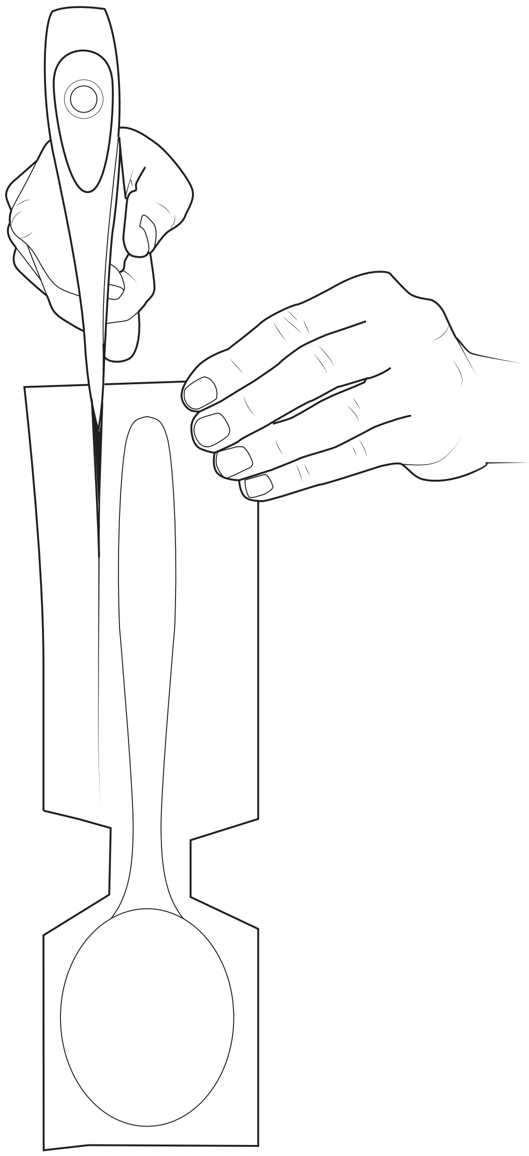


It should be noted that, before shaping with the axe, it is possible to mark guides onto the surface of the blank using pen or pencil. In the sequence illustrated here, a silhouette of the spoon could be marked onto the top face, as seen in the illustrations. Such markings can be useful to guide the axe work, but are not usually adhered to with absolute precision, for three reasons. First, lines drawn onto the surface are removed as wood is wasted so, whilst the silhouette can guide shaping in one dimension, as soon as work progresses to shape the top surface, the lines are lost. Secondly, as described in the next section, when wood is split, there is never absolute control over the split's progress. Any curve discovered in the grain might be either incorporated into the form, or worked around. And third, during the translation from two to three-dimensional form, alternative shapes might present themselves. Because of this aspect of the process, the looser guidance of a centre line running the length of the spoon can be more useful than a more prescriptive layout (Sundqvist 1990, see p.108). If there is an ambition for symmetry about this line, as is common, such a center line can be very helpful through the shaping process.

<u>Splitting to Thin the Handle</u>

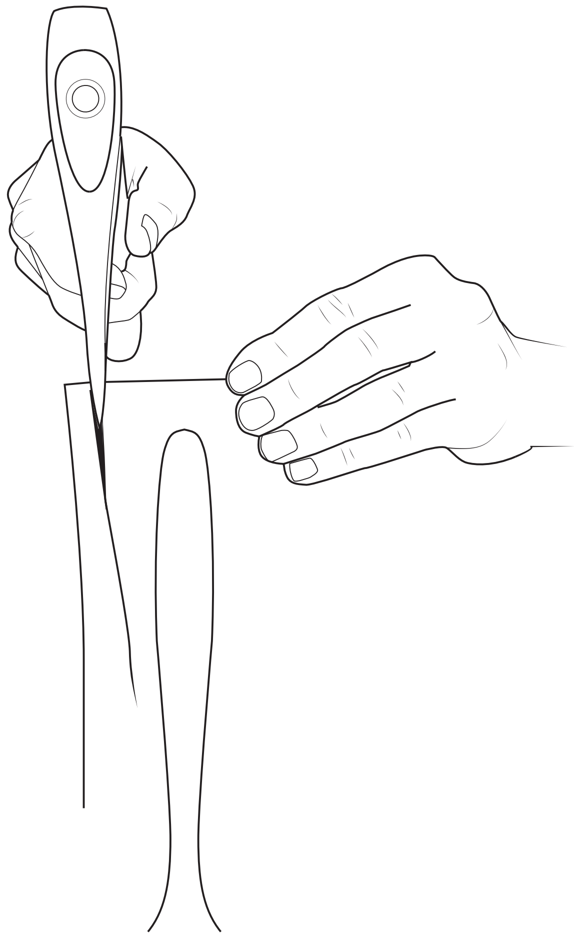
Having established the neck of the spoon, the excess at either side of the handle can be removed. The most efficient way to do this is to once again use the axe to split along the grain. The cuts made to establish the neck allow these splits to be proceed without running on into the spoon's bowl (Figure 5.24).

Figure 5. 24 Splitting down to the neck



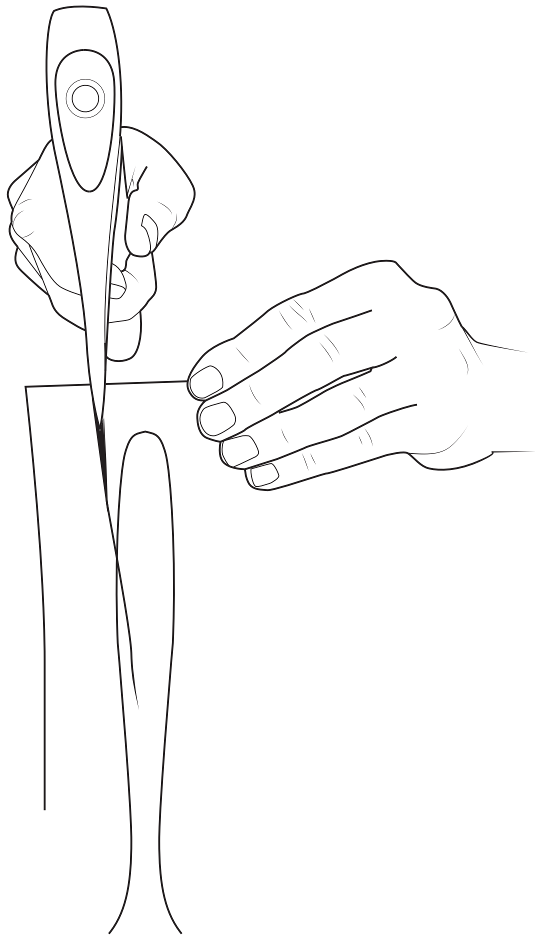
Rather than aiming to split all the waste off in one piece, a better strategy is to make a test split approximately halfway between the edge of the blank, and the anticipated edge of the handle (Figure 5.25).

Figure 5. 25 A test split to check the run of the grain



This test split allows us to check the run of the grain, to see if it travels in towards the handle or away towards the edge of the blank. In the case of the split travelling towards the handle, the final split used to define the handle's edge should be started further out, so as not to end up splitting the handle itself (Figure 5.26).

Figure 5. 26 The potential hazard of not using a test split



The test splits made when thinning the handle demonstrate a feature of step-character not yet discussed—by recognizing the step-character of a technique like splitting with an axe, practitioners can take action to create opportunities for revision, where there would otherwise be none. Where splitting the log in two, as above, uses the axe in a process with no opportunity for revision, this process adds additional steps in order to discover the run of the grain. To return to David Kirsh and Paul Maglio's terminology introduced in the previous chapter (4.2), these steps can be considered more epistemic, than pragmatic, actions. They are introduced to find things out. This kind of tuning of step-character is a subject I return to in the following chapter (6.2.2).

Part 4: Carving with the Knife and Hook Knife

Shaping with the axe is followed by carving with the knife (Figure 5.27) and hook knife (Figure 5.28). The knife is used to carve any flat or convex surfaces and the hook knife is used in concave areas (typically just the inside of the bowl). Towards the end of the axe work, shavings and splits become increasingly perilous, as we approach the more resolved spoon form. There comes a time when splitting parts of the spoon offers too little control, and leaves too rough a finish. Chair maker Peter Galbert is alert to these critical moments of transition, and suggests that, whilst risk might increase, so to do the potential rewards: '[o]ne recurring theme I've come across is that each tool, used in its proper place and to the maximum extent of its ability, will speed the process and leave less work for the next tool. Switching tools too early can make a job laborious' (2015, p.xi). With experience, it is possible to go further with a coarser wasting technique, using a tool like the axe, before making this transition to a finer technique. Again, I believe such situations can be understood as a kind of tuning of step-character.

Figure 5. 27 Carving with a knife

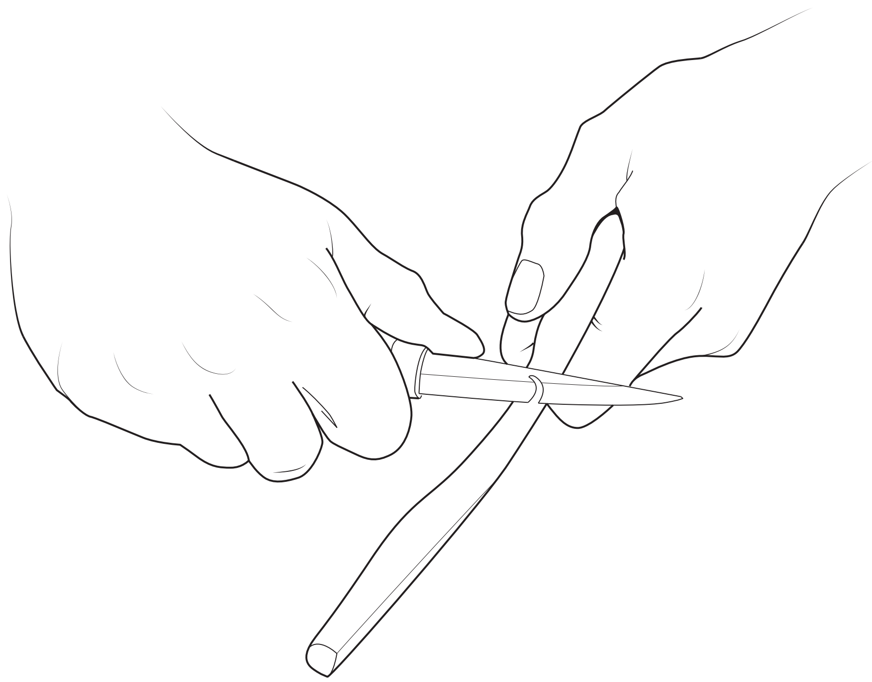


Figure 5. 28 Carving with a hook knife

Where the process of shaping with an axe combines shaving and splitting methods, knife cuts are almost exclusively intended to shave wood and leave a smooth finish. The direction of these cuts is thus critical, so that they may slice wood fibres with the grain. To this end, spoon carving instructional texts (e.g. Sundqvist 1990) focus in detail on the variety of knife-holding methods that should be employed in different situations. These holds enable carvers to apply force safely at a variety of angles and trajectories. To achieve the smoothest possible finish, the last of these cuts can be delayed until the spoon's surface has had time to dry out a little—although more force is required for the cuts, the less pliable fibres can be sliced more cleanly (ibid., see p.118).

One of the most satisfying cuts to make on the spoon is at the back of the neck[7], where the handle is blended into the back of the bowl. In a classic spoon design, the neck profile is narrow in plan and deep from the side (see cross-section B-B in Figure 5.29) (ibid., see p.96), to provide strength where it is required.

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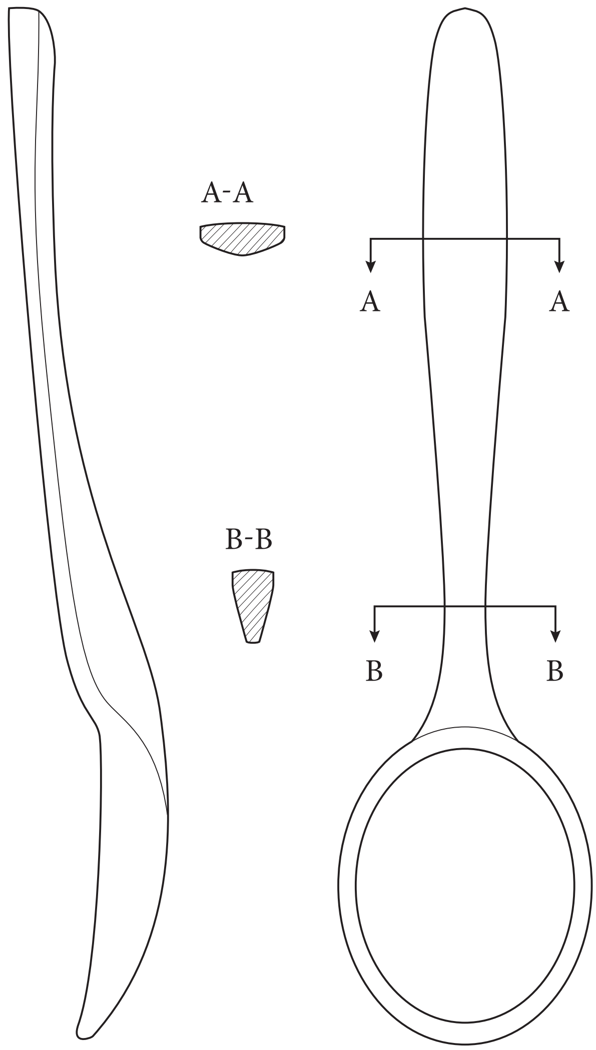
[7] This pleasure is perhaps akin to 'the elation felt by the violent exertion of a strength with which man measures himself against the overwhelming forces of the elements and which through the cunning invention of tools he knows how to multiply far beyond its natural measure', as described by political philosopher Hannah Arendt (1958, p.140)

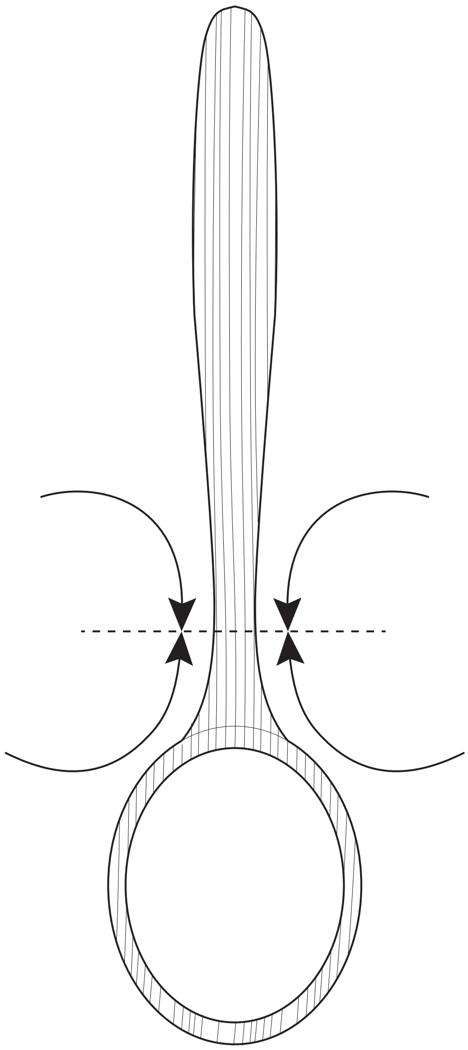
Figure 5. 29 A classic spoon design



The intersection of this V-shaped profile sees the two sides of the neck meet at a ridge that runs down the spoon's centre line. In order to cut smoothly with the grain, and enjoy the reward of creating an even, peeling shaving (Figure 5.30), these cuts are started at the back of the bowl, progress towards the handle and are stopped before they begin to tear, rather than cut, the fibres (see Figure 5.31 for the direction of cuts made with respect the grain). Repeated passes are used to peel off shavings.

Figure 5. 30 Defining the "V-shaped" profile. The dotted line represents the apex of the "V"

Figure 5. 31 The direction of cuts made with the grain



To maintain symmetry about the centre line, and a consistent position for the ridge of the v-shaped profile, these passes can alternate from one side to the other. Also to this end, the thickness of the peelings that result from symmetrical knife cuts can be monitored for consistency. In such instances, the emergent result of the technique exists not just as the object of our endeavor, but also in the material wasted[8]. By monitoring the peelings that result from knife cuts and feeling changes in resistance, we can make fine adjustments to the depth of cut. These adjustments demonstrate a significant difference between the knife's step-character and that of the other techniques throughout the spoon carving process. Whilst using the knife, such adjustments can be made continually, during the cuts, rather than being

[8] This is a feature of shavings also exploited in other areas of woodwork—when assessing the set (depth of cut) of a hand plane, for example, if a less-than-full-width shaving is ejected from only one side of the plane's throat, it indicates that the blade is set deeper on that side.

limited to the intervals between action. Although there are intervals between knife cuts to assess and reconsider the emergent spoon (and these are frequent and fine-grained), there is also much more opportunity to steer the result throughout the action.

5.2.5. Summary of the Step-Character of Carving a Spoon

In the example of carving a spoon, we discover how the various techniques offer different opportunities for the evaluation and revision of an emergent result. I consider these opportunities to be the intervals of step-character. In the following chapter, I explore how the step-character of a technique is thus linked to the questions posed throughout. The relationship between these two aspects of epistemic character, I suggest, plays an important role in structuring practice.

5.3. What is the Nature of the Emergent Result?

The last of this chapter's three questions concerns the *nature of emergent results*. Throughout the example of spoon carving, I referred to the emergent result as it was presented throughout the step-by-step process. I now explore what I mean by an "emergent result" and offer a suggestion as to how its nature may be evaluated.

5.3.1. What is an Emergent Result?

In the previous chapter, I introduced neurophysiologist Nikolai Bernstein's study of skilled blacksmiths (see 4.3.2). Through experiments that employed an early form of motion capture photography, Bernstein investigated the nature of a smith's dexterity. The key finding was that, despite the accuracy with which a smith could repeatedly strike the same point on an anvil, there was significant variability in the arrangement of their arm joints during each hammer swing. For Bernstein, this supported his argument that the essence of dexterity lies not in mechanically repeated, memorized movements, but in an ability to adapt to the emergent conditions of a task. In the experiment, the conditions to which the smiths responded were influenced by the inconsistent recoil of the hammer and the changeable elasticity of their muscles and ligaments. In real practice, however, the dexterity of blacksmiths is challenged to an even greater degree—by the additional variable of the ever-changing piece of hot metal that they are hitting. Each blow from the hammer alters the shape of the work piece and, therefore, the target for the next. As the iron cools, it will deform less for the same force of hammer strike. There is an unpredictability to the outcome of every blow, necessitating the kind of dexterity Bernstein identified: an aptness for continual correction, made possible by a highly-tuned sensitivity to the emergent result.

This is not to suggest that a blacksmith does not have a good understanding of what their completed forging will be like. In Charles and Janet Keller's anthropological analysis of the craft, the 'umbrella plan' is used to describe both this conceptual representation of an artefact and the procedures envisaged for its creation (1996, see p.109; see 3.2.4). A smith's umbrella plan helps to direct the making process but must, Keller and Keller argue, remain sufficiently vague and open to revision. The plan might be supported by a loose sketch, or single dimension to which one part of a forging should conform. To over-specify the result in advance, however, would be at odds with the emergent nature of the process, for '[e]ven the most thorough design and associated plan for action can never be sufficiently detailed, sufficiently precise to anticipate everything that can happen during production' (ibid., p.118) (see also, Suchman 1987). Blacksmiths must be attentive to states of progress which are not knowable in advance, but emerge throughout the process. There is a call and response, or back and forth, between a practitioner and the object of their work. Keller and Keller's notion of the umbrella plan allows for this exchange, by 'containing the expectation that further material and procedural details beyond those specified' will become apparent throughout (1996, p.119).

Whilst their study is rooted in the specifics of forging metal, Keller and Keller, as anthropologists of knowledge, are eager to extrapolate from this setting. They draw on other studies of craft, invention and industrial design (ibid., see p.118) to justify their claim that this emergent quality is not unique to blacksmithing, but also present in other creative fields. In practices that work things out along the way, and must respond to the unpredictability of the material world, emergent results are a common feature. This recalls Andrew Pickering's treatment of scientific practice as a dance of agency (see 3.2.4), a subject I return to below.

For now, I wish to think of emergent results as the answers to questions addressed throughout a technique. When deciding 'how many divider steps should define this side?', for example, the pattern of dots stepped out onto our paper is an answer to this question. It might not be the final answer, it might be tentative or temporary, but it is an answer—an emergent result, which may then be evaluated and revised if necessary. Emergent results need not be limited only to the visual realm—when carving a spoon, using a thumb and finger to assess the thickness of the bowl can provide valuable feedback. And in the waste created when carving with a knife, we also found that emergent results are not necessarily found in the object of our creative endeavor, but as an associated effect. This approach would allow us to expand the idea of emergent results to include things like the sound a hammer is making, or the smell of a saw cut. It is perhaps with reference to these aspects of production that the intimate link between perception and action, as promoted by critics of dualist, linear cognitive models (see Chapter 3), becomes most apparent. Whatever their nature, it should be noted that these answers don't exist in advance of practice, before their material realisation.

5.3.2. Agency and Emergence

In acknowledging emergence, Keller and Keller are following ecological approaches to philosophy and anthropology (see, for a discussion, Malafouris 2013, p. 207) and theorists of situated action, by understanding creative practice to be akin to the 'ripening of an idea' (Bergson 1911, p. 360). This approach focusses on the behavior of the world (of materials) as much as that of the practitioner. As we found in Pickering's metaphorical "dance" between people and the world (see 3.2.4), this behavior is often described in terms of "agency".

To return to a passage that has been quoted by others to illuminate the character of emergence (see, for example, Malafouris 2013, p.217; and Ingold 2000, p.352-3), anthropologist Gregory Bateson asks us to '[c]onsider a man felling a tree with an axe. Each stroke of the axe is modified or corrected, according to the shape of the cut face of the tree left by the previous stroke. This self-corrective […] process is brought about by a total system, trees-eyes-brain-muscles-axe-stroke-tree' (1973, p.318). Here, Bateson describes the back and forth between people and the world, in an effort to avoid anthropocentric interpretations of action. He regards the man-tree-axe system as an indivisible whole that is jointly responsible for the outcome of the task. This ecological account has parallels with the theory of extended mind, which is similarly committed to the idea of an indivisible relationship between people and their environment. The body, writes Andy Clark, is 'just one element in a kind of equal-partners dance between brain, body, and world' (2008, p.56-7).

For Lambros Malafouris, this equal-partners dance necessitates the ascription of *agency* across the constituents of a system (2008; 2013). In the studies of pottery that partly inform Malafouris' work, the notion of agency is a means to account for the role of the clay, the wheel and the potter in a pot's formation. Each of these elements is said to have its own agency. Whilst, as Malafouris observes, we are usually inclined to take sole responsibility for our efforts, and think that "*I* cut down the tree", or "*I* made the pot" (2013, see p.218), in so doing, we ignore the resistance and accommodation of the world (Pickering 1995), and its influence on the task. In the case of tree felling, the fibrous nature of the tree and its predisposition to split in a particular way (see 5.2.3), will co-determine the outcome of each axe blow. In Malafouris' pottery examples, the pot is formed by the system of clay, wheel and potter, with each element exerting a force throughout. Following this understanding, the results of creative practice are caused not by a pre-existing idea being impressed into inert materials, but by a coming together of different agencies.

Although similarly averse to internalist accounts of creativity, Tim Ingold is critical of those invoking the idea of agency to describe the behavior of materials (2007). Ingold equates the attribution of agency to a sprinkling of 'magical mind-dust' (2010, p.28) across the non-human elements of systems. His primary criticism of this approach[9] is that it is only necessary if we make the mistake of thinking of materials as inert in the first place. Were we, as Ingold suggests, to focus on the history of a piece of clay or wood, we would find that

[9] In addition, Ingold believes agency to suggest a somewhat absurd symmetry between a highly skilled organism, like a potter, and a lump of clay (see Ingold 2010, p.94)

it has undergone a life of continual change, ‘forged in ongoing relations with surroundings that may or may not include human beings and much else besides’ (2010, p.31). The point at which a piece of clay is thrown into a pot, or a piece of wood is cut to length, is just one more transformation in this history. If we appreciate that materials are already alive, in that they are both susceptibility to, and the cause of, continual change, Ingold argues that we would no longer need magical dust to bring them back to life.

I’m sympathetic to Ingold’s criticism, and would prefer to avoid introducing jargon like “agency” wherever possible, but I believe the term to have a useful corrective force in fields that might otherwise cast materials, and the techniques for working them, as inert (as described in Chapter 3). In studies of craft practice, like the ones offered by Ingold, Malafouris and Keller & Keller, perhaps there is less need for such correction—the idea of “working with materials”, accommodating their heterogeneity and anticipating unpredictability is already well acknowledged (Sennett 2008). It is in less obviously materially-engaged settings like those described by Pickering (see 3.2.4), however, that I suggest the notion of agency can be more helpful. For the present study, I am eager to demonstrate that emergence is not only a feature of workmanship of the risky kind, but present throughout any designing and making practice wherein things must be worked out along the way. In this effort, the idea of material agency, understood as a capacity to resist or accommodate certain forms, provides a useful concept.

5.3.3. The Performative and Representational Idioms

Underlying Pickering’s analysis of science practice is a contrast between what he calls the *performative* and the *representational* idioms for understanding the discipline. Pickering claims the established position is to see scientific practice as representational. This ‘casts science as, above all, an activity that seeks to represent nature, to produce knowledge that maps, mirrors, or corresponds to how the world really is’ (1995, p.5). The alternative, performative stance, is what Pickering tries to capture through his description of science as a dance of agency. This is to ‘start with the idea that the world is filled not, in the first instance, with facts and observations but with *agency.* The world, I want to say, is continually *doing things*, things that bear upon us not as observation statements upon disembodied intellects but as forces upon material beings’ (1995, p.6, emphases in original). A fundamental aspect of scientific practice illuminated by this story, and one which is not adequately explained in the representational idiom, is its temporally emergent nature. In a performance that relies upon both parties (as in the dance of agency between people and the world), we are never quite sure what might happen. Rather than hold on to fixed goals, Pickering's studies demonstrate how emergence forces scientists to tune both their equipment and their expectations. There is always the potential for learning and surprise.

In the case of science, practitioners must tune their approach in an effort to find out what things are like. The goal is usually to develop descriptions of the world[10]. Design practice, I suggest, is instead an effort to find out what things could or should be like. The tuning made in response to emergence throughout the techniques of designing and making is an effort steer the result in a favourable direction.

It is important to be clear that I'm not just describing what might be considered the "practical" consequences of emergence—the high winds that make a bridge wobble, or the reflective skyscraper that focusses the sun's rays onto a footpath. I'm also describing the judgements made throughout a process that might be of little utilitarian consequence, but are nonetheless vital to the success of the outcome. A sensitivity to the subtleties of an artefact's properties is a key feature of design practice (Chamberlain and Roddis 2003), and one, as described in the following quote by architect Christopher Alexander, that is often best supported through a performative approach.

> 'The truth is that no one can tell what the three-dimensional reality of the building is going to be based on a few pencil strokes or a few lines on a computer screen. [It does not enable us to make architectural decisions based upon what] the light is like, what the view is like, where the plants will grow, where you feel like walking, where you feel like sitting, what natural intuitive response a group of people will have to a particular room (if it is too high, too low, too wide, too narrow, too strangely shaped, too distant in feeling from the garden or from the room next door), where the sun is going to shine on the floor in winter, whether one can hear sounds from one room to the next, and so on—a thousand things.' (2002, p.245)

For architecture—a discipline that has, since Alberti's era, been founded on the principle that such planning is possible—Alexander is obviously a controversial figure[11]. I introduce his work here, however, because it serves to illustrate what might be considered an insistently *performative*, and *non-representational* approach to design. Continuing on this theme, I now present this chapter's last study of making.

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[10] Throughout *The Mangle of Practice*, Pickering acknowledges this continuing significance of representations, as the predominant outcome of science (he just aims to tell a more materially-engaged story of how they are arrived upon)

[11] I return to criticisms of his work in Chapter 7.

5.3.4. Two Methods for Making Paper Planes[12]

Method 1. Take a single piece of A4 paper and, using no further equipment, fold, crease and (if necessary) tear it until you have created a plane. To ensure this task is non-routine, and thus analogous to a “real” design process, it is important to attempt to create a novel design (rather than following a pattern of folds used previously).

Method 2. Using as many sheets of paper as you need, and any drawing equipment you like, design your plane. Following this method, you are not permitted to bend, fold, crease or tear any pieces of paper whilst designing. All paper must remain flat until such a time as you have completed the design. Then you must mark all necessary fold lines and instructions onto a sheet of A4 paper, before (strictly) following this guidance to create your plane. Again, to ensure this task is non-routine, it is important to attempt to create a novel design.

This brief exercise allows us to consider the nature of two very different emergent results. Using *Method 1*, there is a back and forth between ourselves and the emergent result. We do something—make a fold, reverse a crease, tentatively bend a corner—and the resultant properties of the nascent plane present new information, questions or challenges. The emergent result helps us to evaluate how things are going. Decisions can be made, and adapted, throughout the process. In this way of working, action is not merely pragmatic (as in an effort to realise a predetermined goal), but also epistemic, in that it is directed towards improving our knowledge of the task and its possible outcomes (Kirsh and Maglio 1994). Each fold is thus a way of making the plane, and a step towards finding out how the plane should be made. *Rather than maintaining an overall ambition for the plane’s design, attention is dedicated to a proximate idea for the next fold*. After every step, we are presented with a new set of questions. I suggest the experimental nature of this process—its striving for, and generation of, both knowledge and a result—give it the quality of a dance of agency, and map onto the performative idiom. The plane is made in real-time, through a sequence of decisions that have not been collapsed in advance, within a model of reality.

By the time we come to fold the plane designed through *Method 2*, the movements are no longer tentative, and the finished form has been almost completely predetermined. In this

[12] The exercise described here is one I devised for three-dimensional design students. Having run the class on several occasions, I now find it best to have students swap their responses to the second method with one another, before folding them. This has the same effect of exchanging answer sheets in a quiz—it removes the temptation to cheat. The exercise finale—a competition to see who has made the plane that can fly the furthest—usually provides good evidence for the limits of representation in the design process.

case, decisions about where folds should and shouldn't be have been made with respect to a model. Through the sketches we make in advance of folding we create this model, and make best guesses as to the emergent form. Whilst the sketching process can be considered similarly epistemic (as described by Gedenryd 1998, see 3.2.1), it is limited by the nature of the emergent result. Our drawings do not pose the kinds of resistances encountered when actually folding a piece of paper. Nor do they accommodate the experimental aspects of tentative folding. They do not allow us to access information about our progress in the same way. Any surprise, affirmation or disappointment must be anticipated through the model. To be clear, I suggest that this way of working maps onto Pickering's representational idiom, wherein all the important work takes place in a setting removed from the materials of practice. Through our sketches, we must imagine the agency of paper.

It should be stated that it is probably not beyond the limits of singular human intelligence to plan all the folds required for a good paper plane in advance. But (and the frustrating contrivance of *Method 2* is intended to raise this question) why would you want to? Why would you take a detour into representation when a performative approach is available? Here, we shift from the theme of Pickering's earlier work (namely his efforts to study the nature of techno-scientific practice) towards his more recent emphasis, which is to explore the implications of his performative story and how, if we grasp its message about being in the world, we might act differently (2008; 2013; 2014). For Pickering, the dominance of the representational story brings with it a detour away from material engagement and towards abstracted knowledge. At every turn, Pickering identifies a tendency, across modernity, to make models of the world, make solutions with respect to those models, put the solutions back into the world and then expect them to behave as expected. The failings of this approach, as discussed by Christopher Alexander, is a topic I return to in Chapter 7.

5.3.5. Summary of Emergent Results

The difference between the two methods for making paper planes may be summarised by stating that *Method 1* engages with real material agency and emergence, whereas *Method 2* models that material agency and emergence. I suggest that this identification, of the variously "performative" or "representational" nature of emergent results, may help to guide investigations of epistemic character.

The example of paper plane making serves to demonstrate the extreme positions of the "performative" and "representational" approaches to practice. In doing so, I am wary of reinstating a design vs. craft dichotomy into the discussion. As described in Chapter 3, however, I remain insistent on the plan-*making* nature of design processes, and see no reason to characterise any design practice as necessarily representational. As an educational exercise, for instance, I have used the paper plane task to introduce students to designing with sheet materials, in advance of a brief that requires them to design a folded pendant light. During this subsequent project, the performative, trial-and-error approach to making *models* of the lights remains far more productive than a sketchpad-based method. Central to this success, I believe, is the idea that the two approaches focus attention differently. As described above, when folding paper to design, attention is focussed not on maintaining an overall ambition for the whole design, but on a proximate idea for the next fold. After every step, we are presented with a new set of questions. This is in sharp contrast to the technique of drawing a design for a pendant light, wherein our attention would not be structured in the same way.

This feature of performative practice—the way an emergent result directs and informs decision making *along the way*—suggests that we should pay attention not just to the qualities of a *finished* emergent result, but its influence throughout a technique[13]. This is a subject I return to when comparing three-dimensional furniture prototyping methods with two-dimensional drawing techniques (6.5.4).

The question for design practice is how to capture the agency and emergence of material-engagement throughout these techniques. How can we avoid collapsing decision making into a period of time in advance of emergence, and instead employ techniques that structure decision making around rich engagement with the world? How can our modelling become performative?

5.4. Summary

In the above examples, I have introduced how investigations of epistemic character may be pursued, through the three questions: *What are the questions posed by a technique?*; *What is the step-character of a technique?*; and, *What is the nature of an emergent result?* Although I have discussed these questions individually, whilst focusing on particular techniques, it should be noted that they are all related. We could even say that *step-character* presents the opportunities for *questions to be posed* and answered with reference to the *emergent result*. This is why step-character has come, for me, to be the most significant of the three

[13] This is a point I feel is often missed by studies of the techniques of design "representations" (e.g. Goel 1995; Pei, Campbell & Evans 2011; Self 2011; Self, Dalke and Evans 2009)

questions—it provides the “structure” of epistemic character. In the next chapter, I consider the relationship between *the questions posed* and *step-character* in more detail.

I fear that to go too far with an attempt at a conclusive narrative of epistemic character would, however, be premature. As described in my introduction to this chapter, I have presented the above topics as questions to avoid suggesting a declarative anatomy. Although, as I have argued elsewhere, (Luscombe 2018), I believe the idea of epistemic character to have much potential, I recognise that the ideas presented here are, in their own way, emergent.

6. Making Things Up

I have so far presented a descriptive account of three questions we may ask of epistemic character, without going too far to suggest what preferable answers to those questions might be. This chapter, however, is an opportunity to discuss how the epistemic character of techniques may support, or potentially compromise, design processes. I will once again do this with reference to the specifics of particular occasions of workshop practice. This is an effort to both draw out generalities, and give further examples of how investigations of epistemic character may be pursued.

The main theme of my discussion centres on the question of how techniques distribute decision making throughout a process. This is an idea that combines the interests both of the theoretical foundation of the research, and the subsequent descriptions of practice. It takes influence from the claims made in Chapters 3 and 4 about how we use the world to support cognition, and applies them to a suggestion of how we should aspire to utilise techniques throughout design processes.

To summarise the topic at issue throughout this chapter, it can be understood with reference to the following quote. In his instructional account of wood carving techniques, Wille Sundqvist presents two technical choices for roughing out a spoon blank. The first of these describes how a bandsaw may be used to cut the shape from a log, and the second describes the alternative approach of using an axe (as I detailed in the previous chapter, see 5.2). On the subject of axe use, Sundqvist writes;

> 'Roughing out a spoon blank with an axe requires some practice to do well, but it is not dangerous if you follow proper procedures, and it does give you very direct control of the shaping process. A sense of design that comes from using simple tools cannot be had from machines' (1990, p.106)

Sundqvist leaves his point there, moving straight back into a discussion of what kind of axe to use, and how to avoid cutting off your thumb. By the end of this chapter, however, I hope to have examined the concept underlying Sundqvist's claim that "a sense of design that comes from using simple tools cannot be had from machines". I argue that the notion of epistemic character can offer a new insight into such an idea. My ambition, however, is not to reinforce the kind of dichotomy between machine and hand tools that Sundqvist's somewhat mysterious quote leads us to infer. It is instead to suggest that there is a more fundamental distinction than those between hand and machine, or craft and industry (as were dissected and found wanting by David Pye, see 4.1). I argue that a more valuable distinction can be made between *processes through which things emerge step-by-step*, and *processes through which things are planned in advance of their execution*. In the first of these models, finer-grained decisions are distributed throughout the process (Gedenryd 1998, see p.131), with reference to an emergent result. In the second model, coarser-grained decisions are required to be made in advance of their material realisation. I begin with architect Christopher Alexander's analogy, "The 30 Coin Experiment". As will become clear, Alexander, who I discuss in more detail in the following chapter, is an advocate of step-by-step processes in all creative practice.

6.1. The 30 Coin Experiment

In a simple illustration of the merits of 'step-by-step adaptation' during the design and construction of buildings, Alexander asks us to imagine a system with 30 variables (2002, p.236). Each variable is represented by a flipped coin, which is considered to be successfully adapted when it lands on heads, and unsuccessfully adapted when it is tails. With the goal of tossing all 30 coins so they lie in the heads position, Alexander proposes two possible approaches. The first "all-or-nothing" method is to toss all the coins at once, in the hope that they land as heads simultaneously. If even one coin lands on tails following this approach, the procedure must be started again. The laboriousness and time-consuming nature of such a method is demonstrated by Alexander's calculation that, if the all-or-nothing method was employed at a rate of once a second, the probability is that it would take three hundred years to land on 30 heads at once. The second strategy introduced by Alexander is the step-by-step approach. Following this method, each coin is tossed individually, until it lands as heads. Then the next of the 30 coins is tossed, and so on. Alexander estimates that this step-by-step approach would take two seconds per coin, and one minute in total.

For Alexander, the variables represented by the coins are analogous to the decisions taken throughout the process of design and making buildings. It follows, claims Alexander, that from large scale decisions like how best to arrange a city, down to the minutiae of, for example, the height of a windowsill, the step-by-step approach will be more successful. The point made by the coin experiment is thus at the heart of Alexander's thesis on the art of building. It demonstrates what is wrong with contemporary building practices and their prioritisation of the creation and adherence to plans, over and above "empirical" full-scale prototyping and improvisation. In trying to correctly define the thousands of variables found in any building in advance of its production, Alexander believes that we set ourselves an impossible task. Instead, Alexander claims, 'to make things come out right in the built environment […] there is a simple condition that must be met. The process must go gradually, in a way that allows assessments, corrections, and improvements to be made [..] throughout the structure, at all scales and at all levels' (ibid. p.237).

As is obvious, Alexander's position is at odds with the processes followed by almost all contemporary architects. I return to criticisms of his approach in the next chapter. Nonetheless, the coin flipping analogy helps to introduce the theme of this chapter, and suggests (albeit in a polarised way) the potential significance of the distribution of decision making.

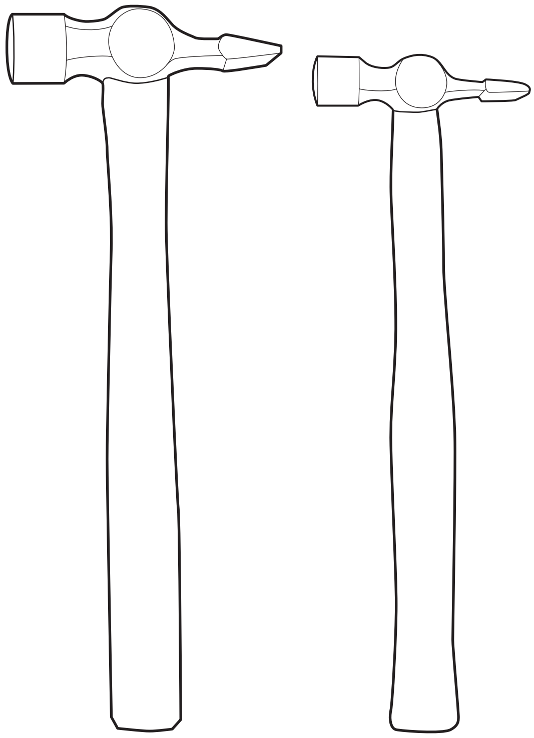
6.2. Selecting a Hammer

In Chapter 4, I developed an account of the simultaneously epistemic and pragmatic nature of tool use at the most basic level. This was built around the example of hammering. I now aim to show how a choice between two different hammers reveals something fundamental about the distribution of decision making throughout productive processes. This is a study that considers *step-character* and *the questions posed* by a technique. Whilst this is not an example involving what would usually be considered "design decisions", it nonetheless provides a useful illustration of how the opportunities for reflection and revision can be distributed differently. Later in this chapter, I go on to consider techniques where more significant decision making takes place, during the prototyping of furniture (see 6.5).

6.2.1. The Frequency of Opportunities for Revision

Imagine choosing between two different hammers (Figure 6.1) to knock a panel pin into a piece of timber. Both hammers share the same Warrington pattern studied in Chapter 4 (see 4.1), which is adept at both setting pins (using the cross peen) and driving them home (using the round face). The difference between the hammers lies in the size and weight of their heads, and the length of their handles. Whilst it would be possible to accomplish the task of knocking in the panel pin using either hammer, there remains something to be said for the differences in their use.

Figure 6. 1 Two warrington hammers



Using the largest, 14oz hammer, it should be possible, with practiced technique, to drive the pin home using fewer blows than with the 10oz hammer. Owing to its greater weight, the 14oz hammer has the potential to deliver a more forceful strike. Exaggerating this distinction, it might even be possible, given a large enough hammerhead, to deliver all the requisite force in just one blow. The problem with this, however, would be the difficulty of delivering the single blow with accuracy, so as not to bend the pin or glance its head. The repeated strikes that we commonly associate with the action of hammering can thus be understood not just as necessary steps towards a goal, but also as opportunities for sensing progress and revising our approach (see 4.4). In Figures 6.2 and 6.3, I illustrate these differences in the steps taken with each tool.

Figure 6. 2 The progress of a pin when driven with a 10oz (above) and 14oz (below) hammer

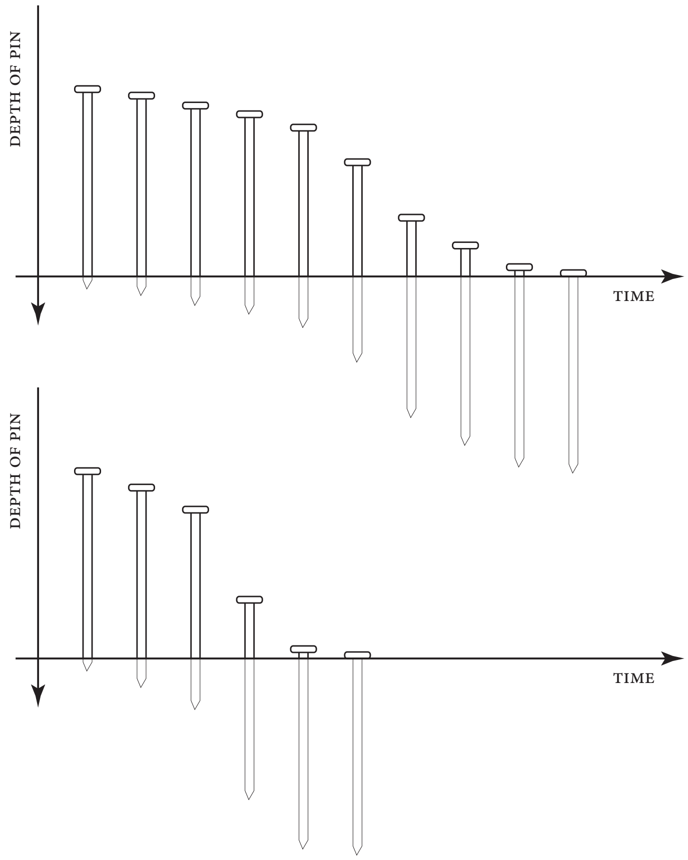
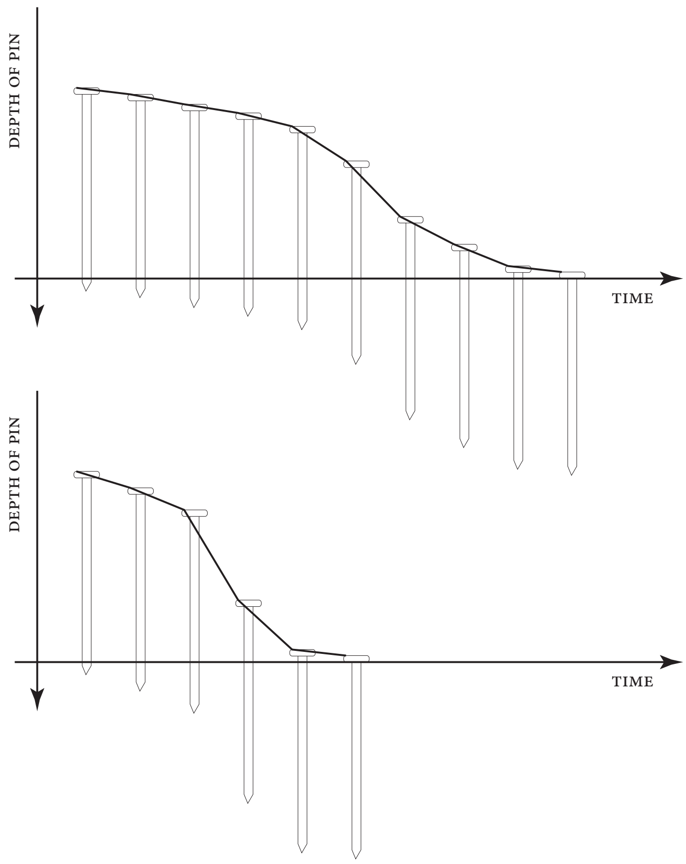


Figure 6. 3 The progress of pins as line graphs. 10oz above and 14oz below.



The diagrams show the distance travelled by the pin for each strike. The 14oz hammer drives the pin using fewer blows of greater distance, and so offers fewer opportunities for revision. If we read these two diagrams as line graphs (Figure 6.3), where the heads of the pins form the points, we find the 10oz hammer creates a longer, shallower line—the process of knocking in the pin involves more steps of a smaller distance. It is a smoother journey filled with opportunities for revision. The heavier hammer, by contrast, offers fewer chances to sense progress and adjust our approach.

The example of two hammers is an illustration of how a technical choice between two tools may influence the step-character of a technique. I suggest that the repeated strikes of hammering are analogous to the opportunities for assessing an emergent result during other techniques. Throughout this chapter's theme of distributed decision making, step-character thus plays an important role.

Before pursuing this idea in the context of other techniques, I first wish to clarify two points from this example. First, I note that the step-character of the different hammers should not (contrary to the simplified account just offered) be considered as properties of the two tools—a practitioner may tune the step-character by varying their technique. Second, I consider what "decisions" are being made in this example, and show how they vary in significance. This is to return to the idea of *techniques posing questions* (see 5.1). Importantly for the topic of distributed decision making, I suggest that these questions may vary throughout a technique, in both their nature and significance for design practice.

6.2.2. Tuning the Behaviour of a Tool to Modify Its Step-Character

If they chose to do so, a practitioner may use the 14oz hammer to deliver blows of less force—they could adjust their technique so as to take a greater number of strikes to complete the task. It must be stated then, that the step-character of a process is not only determined by the tool itself—it is a result of the whole system of the tool, the material being worked and the practitioner (see 2.6.3). The size and weight of the hammer does, however, have an important influence upon both the speed with which a pin may be driven, and the opportunities for revision throughout the process. Alternative hammers encourage and support different approaches to a task. By selecting a hammer appropriate to the size of the pin, and with respect to personal preference, a practitioner tunes the whole system to work in their favour. The fact that even similarly intentioned hammers, such as the two Warringtons here, are routinely produced in increments of 2oz is evidence of the importance of this tuning[1]. During techniques that demand a practitioner's dexterity, such tuning is commonplace. As tools are used both to complete a task and provide feedback on its progress, being able to modify the frequency of this feedback is an important advantage.

6.2.3. The Variable Decisions of Hammering

As a hammered pin begins to travel into a piece of timber, its position is increasingly determined by the surrounding wood fibres (see 4.1.1). The "decisions" made after the first few hammer blows are, therefore, relatively insignificant. For clarity on this point, we can look to the questions posed by the technique at various times. Just before our first few hammer taps, we are asked to confirm the location and angle of the pin. We must be sure that the pin will join the parts we intend to be joined, and not burst out of the side or back of

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[1] The tuning does not end with the selection of the tool. Once a hammer has been selected for a job, its behaviour can be altered by adjusting where we grip the handle (Sellers 2016, see p.471). Holding the hammer close to its head offers greater sensitivity and control, but less power. Holding the handle further away from the head allows a greater force to be employed, but to the detriment of sensitivity and control. These fine adjustments made using alternative grips demonstrate how the step-character of a technique may be subtly tuned throughout practice This is the same idea encountered in section 5.2.4, where test cuts could be made with the axe, to determine the run of the grain.

the timber. These are relatively significant questions. Once the pin's eventual location is increasingly determined however, the questions posed are less significant. Each strike at this stage is a call and response between the practitioner and the emergent result, focussed around the question of how not to bend the pin, or how not to bruise the timber. Unless a non-routine event such as these does occur, we are not tasked with any more significant questions. Just as the risk of a technique varies throughout then (see 4.1.2), so too does the nature and the significance of questions posed.

6.2.4. Refining 'Step-Character' and 'Questions Posed'

In the previous chapter, I identified that *step-character* determines the frequency of opportunities for the assessment and revision of an emergent result, and *the questions posed by a technique* focus attention and priorities during techniques. I now suggest the example of choosing between two hammers develops our description of these aspects of epistemic character in the following ways;

- Step-character is not a static property of a technique or its elements (the practitioner, tool or material); it may be tuned by the practitioner.
- The questions posed by a technique vary throughout. These questions influence the nature and significance of the decisions to be made at different times.

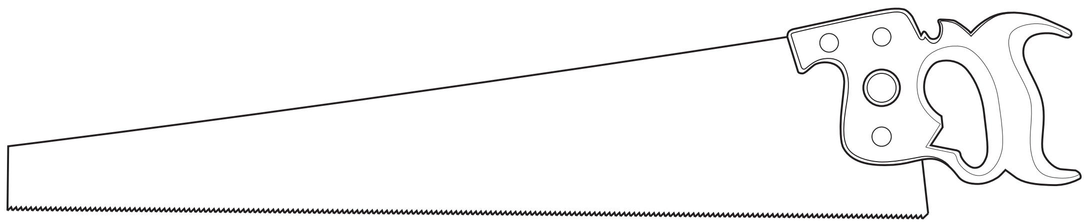
Both of these qualifications acknowledge the dynamic nature of epistemic character. It is the last point in particular, regarding the variable nature of questions asked throughout a process, that is critical to this chapter's investigation of distributed decision making.

6.3. Wayfaring and Transport

Before studying further instances of tool use, I return to Tim Ingold's observations on the nature of sawing (2010, see p.51-62), as discussed in Chapter 5 (5.2.1). Comparing his "processional" account of hand saw use to the experience of using a guided power saw, Ingold associates these different techniques with his concepts of 'wayfaring' and 'transport' (ibid., p.59). I outline Ingold's discussion here because I believe the distinction he draws between wayfaring and transport can be helpfully applied (with some modification) to my consideration of the distribution of decision making throughout techniques.

6.3.1. The Wayfaring Handsaw

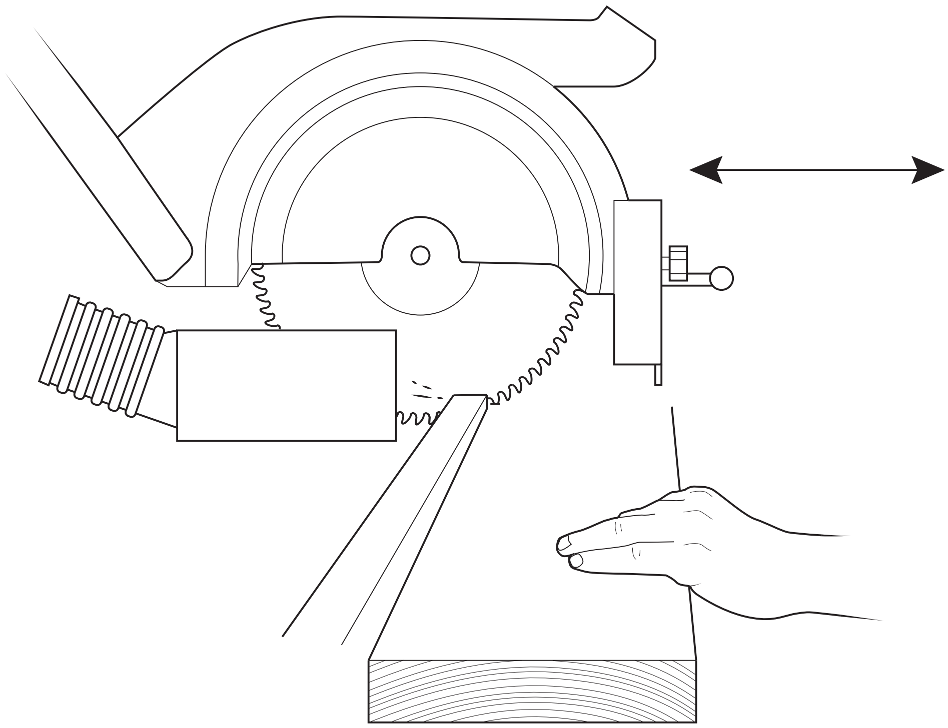
Figure 6. 4 A panel saw



Ingold describes the nature of panel saw use in detail (Figure 6.4). In a fine-grained analysis of sawing through a board, we read about how the first 'staccato' (ibid., p.55) strokes give way to a slower rhythm as progress is made, before the cut must be finished with care, so as not to split the last few fibres of wood. Sawing, claims Ingold, is akin to a journey where 'every step is a development of the one before and a preparation for the one following' (ibid., p.53).

Ingold then contrasts the process of sawing a board by hand with that of using a radial arm crosscut saw (Figure 6.5). Where the processional quality of hand saw use necessitates many smaller steps be made throughout the cut, machine cutting reduces the rhythmic back-and-forth of the hand saw to a single slice. Rather than attending to the progress of a cut throughout, and making subtle adjustments to correct or incorporate errors, the predetermined operation of the crosscut saw sees practitioners 'intervene solely in the intervals between stopping and starting' (ibid., p.61). For the crosscut operator, these are the periods when 'all the significant action takes place: when plans are laid, instruments reset and materials assembled' (ibid., p.59).

Figure 6. 5 A radial arm crosscut saw



Reflecting on this difference between the rhythmic strokes of handsaw use, and the rotary pass of the crosscut saw, Ingold makes an association with his distinction of wayfaring and transport. The exploration of these two modes of movement forms part of Ingold's wider anthropological project[2]. With a slight shift in their application, I hope to show how this distinction can helpfully illuminate this chapter's theme. I believe the concepts of wayfaring and transport can illustrate the difference between processes that distribute decisions throughout, and those that require them to be made in advance.

For Ingold, the critical difference between these two metaphors is that transport emphasises the connection of discrete points, whereas wayfaring emphasises a 'continual engagement with the field of practice' (ibid., p.59). The nature of transport is essentially 'destination-orientated' (ibid., p.150). As idealised in the straight lines of a city's subway map, the aspiration is to link destinations as directly as possible. Between our stations of departure and arrival, we may "switch-off", reassured that the network will carry us to where we want to be. This 'decoupling [of] perception and motility' (ibid., p.152), argues Ingold, promotes a model of movement that would, in an ideal world, be instantaneous. It is what happens at

[2] As part of Ingold's effort to study the world and its inhabitants by 'tracing the multiple paths of becoming' (2010, p.14), the nature of movement is one of his fundamental themes.

our destinations that matters, not what occurs along the way. Wayfaring, by contrast, is a model in which we must pay attention to our surroundings throughout a journey, as the environment continually presents us with alternative paths and destinations.

According to Ingold, wayfaring is thus akin to the processional quality of dexterous tool-use, where steps flow into one another and revisions and accommodations are made throughout. The nature of transport, by contrast, has its parallel in machine operation. In Ingold's description of cutting timber, this takes the form of the crosscut saw.

6.3.2. An Appropriation of Wayfaring and Transport

I believe the metaphors of wayfaring and transport can be usefully applied to describe how decisions are distributed throughout workshop practice. My application of these concepts, however, is different to Ingold's. In my analysis of using a hand saw or crosscut saw, for example, *both* techniques are more closely related to the model of transportation than wayfaring.

This divergence is because of my emphasis on a technique's epistemic character—specifically, how it structures the process of working things out. I interpret the steps (or destinations) of a technique as opportunities for the assessment and revision of an emergent design. Because the questions posed by a technique varies throughout these steps, I recognise that they do not present equally significant decision-making opportunities. Once a handsaw cut has been started, for example, its destination is well-defined[3]. The first phase of strokes set it on a course. Once the saw becomes guided by its own kerf, the subsequent steps and their associated questions are far less consequential. Because I am interested in those questions that prompt significant decisions to be made about the emergent design, this is an important distinction.

Regarding the operation of sawing a board of timber across its width then, I suggest that, whether it is performed using panel saw or crosscut saw, the significant decisions are concentrated in the very first steps. When discussing the moment in advance of using a handsaw, Ingold himself is alert the importance of this time. He observes that the Greeks even had a special word, *kairos*, for just the right moment to begin (ibid., see p.54). Although Ingold doesn't say so, I suggest we may presume that the machine operator experiences a similar moment, just as they are about to switch on the crosscut saw. As

[3] Here I refer specifically to the panel saw of Ingold's example. This is not necessarily true of all types of saws. See, for example, the coping saw described in section 6.6.1.

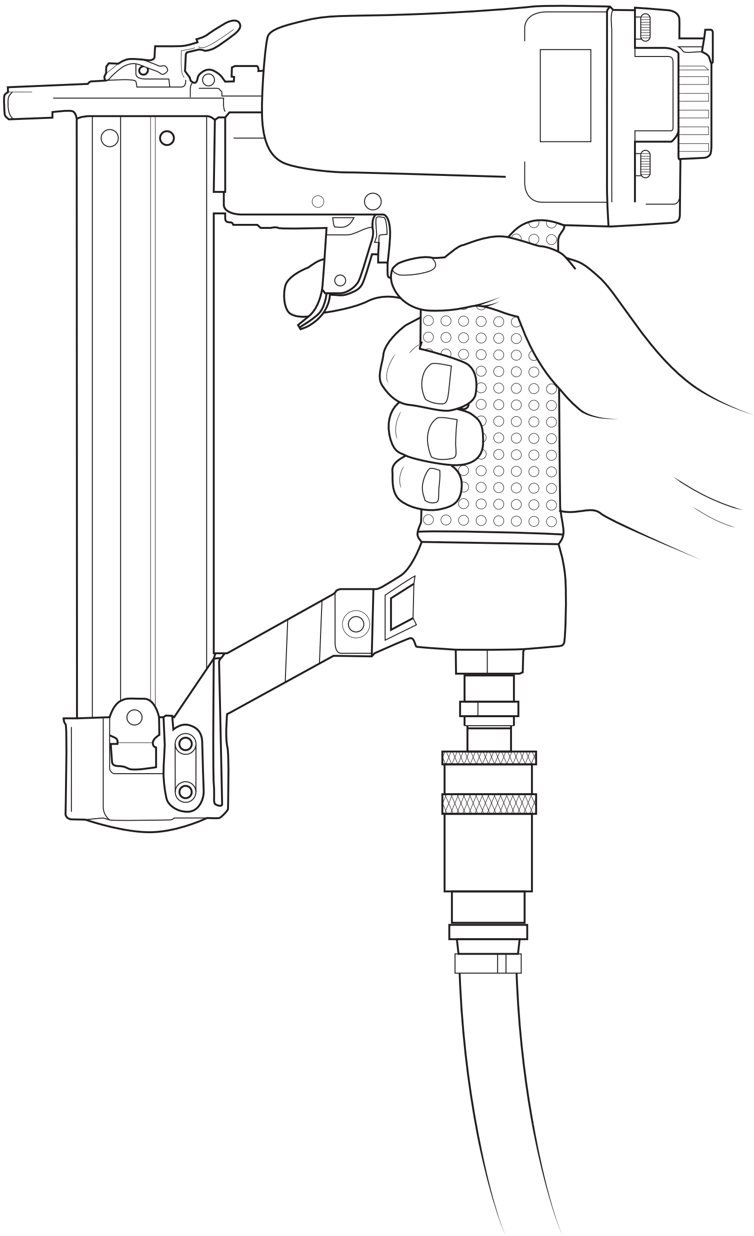
discussed in the previous chapter, the maxim of *measure twice, cut once* captures the significance of this time.

6.3.3. A More Certain Hammer

Further to this point, we can return to my previous example of hammer use. In the context of hammering, the equivalent of Ingold's crosscut saw might be a hammer that could sink a panel pin in just one blow. In order to avoid spoiling the job, such a hammer would need to be guided along a pre-determined path, towards a panel pin held in an exact position. Rather than the rhythmic strikes of repeated hammer blows, we would see a single, undeviating blow, just as in the single pass of a powered saw. There would be no opportunity for revision throughout. A practitioner would intervene only in the periods between each hammer strike. And, rather than the multiple blows made with the 10oz and 14oz hammers, the single-hit hammer could drive home the pin so quickly as to be apparently instantaneous.

In fact, we need not think of this hammer as an imaginary tool. Whilst it might look dissimilar to the Warrington pattern, such a machine does exist—the powered nail gun drives pins in this way (Figure 6.6). And the experience of using a nail gun is indeed one of speed, as pins are punched almost effortlessly, with attention paid only to positioning the pin and then moving to the next point. Just as Ingold's hand saw has its mechanical counterpart in the rotary crosscut, the nail gun is a mechanised hammer. It replaces the repeated strikes of the human-powered tool, and the sequence of occasions at which a practitioner must sense the progress of the task, with a single blow. Under Ingold's analysis, we see the wayfaring-like quality of hammer use replaced by a transport-like pre-determination.

Figure 6. 6 A nail gun



As in the example of sawing, however, I consider both methods of driving a pin, whether hand or machine powered, to be more akin to the model of transportation than wayfaring. In both cases, the significant decisions are made early on. We are first asked to make sure that we locate the pin in the right place and at the right angle. The mechanical equivalent of those tentative taps with a hammer is a period focussed on siting the gun correctly. Once the trigger is pulled, of course, the determining mechanism takes over and the subsequent phases of hammering are collapsed into an instant. The outcome of the process becomes certain. But this is only in symmetry with the increasingly determined travel of the hand-hammered pin, as it works its way into the timber[4].

6.3.4. The Dynamics of Risk and Wayfaring

For Ingold, the distinction of wayfaring and transport is 'precisely parallel' to David Pye's workmanships of risk and certainty (ibid., Chapter 4, note 1, p.246): wayfaring is risky and transportation certain. Whilst I appreciate the reasoning behind Ingold's equivalence, I believe this treatment of the subject misses both the dynamic nature of risk, and the changeable inevitability of the destinations of practice. Both of these features can be found in the example of sawing.

The risk of sawing a board lessens as the saw becomes guided by its own trajectory. As the plate of the saw settles into the emergent kerf, it is inclined to continue along the same path. Once held in this jig of its own making, only minor adjustments can be made to the saw's direction. The destination of Ingold's wayfaring sawyer thus becomes ever more fixed.

To return to the subway trains of the transportation metaphor, at this stage, the practitioner finds themselves on a fixed track. Although they might be driving the train, rather than mindlessly sitting in the carriages, they are nonetheless on their way to a well-defined destination. I believe Ingold's static categorisation of hand saw use as both an instance of the workmanship of risk, and a model of wayfaring, ignores this shifting dynamic.

Just as the workmanships of risk and certainty should not be considered discrete categories into which techniques may be placed, I suggest we might locate the concepts of wayfaring and transport as the poles of a continuum. In the same way that a technique's risk varies over time, so too does the fixity of its destination. And with this changing fixity comes a variation in the nature and significance of the questions it asks. To properly appreciate the distribution of decision making throughout a technique, I believe we must be alert to the dynamics of these questions.

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[4] Here I am starting my analysis of both the hammer and nail gun just before the "action" begins (with the first hammer strike, or the trigger pull). Whilst this might blur a boundary between design and workmanship that Pye would rather leave intact, I do so here in accord with Malafouris' suggestion to 'carefully define the portion of time encapsulating the event we want to describe […], if we want our account of the causal hierarchy of events not to trivialize the complexities of their cognitive ecology' (2013, p.223), as discussed in 2.6.14.

6.3.5. Summary of Wayfaring and Transport

I believe that Ingold's distinction between wayfaring and transport can be usefully applied to the present discussion of epistemic character, but only in a modified form. This is a modification made according to my interest in the influence techniques have on decision making. I suggest that;

The metaphor of transport can be applied to occasions that require us to decide upon a goal without reference to incremental feedback. Our destination is specified in advance and our journey could be collapsed in time, without affecting the result.

The metaphor of wayfaring can be applied to occasions that enable us to make decisions along the way, with reference to incremental feedback. We progress step-by-step, from one proximate destination to another.

My focus on technique sees me associate epistemic character with the dynamic of a technique, rather than as a property of tools. And, crucially, I also suggest we recognise that the wayfaring or transport-like nature of a technique need not be a static characteristic. Like risk, it may change over time.

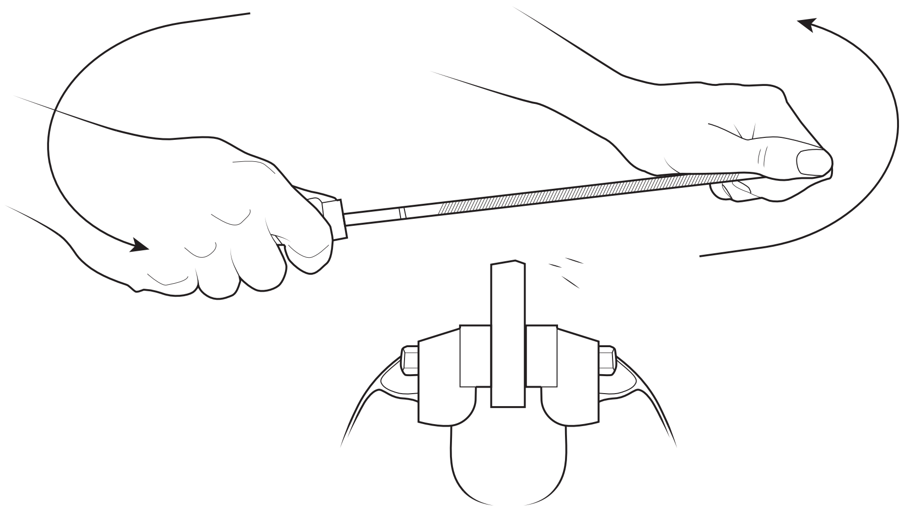
6.4. Distributed Decisions in Workshop Practice

I now consider how other techniques distribute decisions in workshop practice. I begin with a short comparison between two metal-wasting techniques; hand filing and belt linishing. This builds on the example of hammer use, offering a context in which different step-characters distribute (potentially more significant) decision making. The next example compares two woodworking techniques; using a thicknesser and a hand plane to waste the surface of a board. Here I return to the ideas of wayfaring and transport and look at the link between dexterity and wayfaring. This enables me to develop a novel interpretation of the value of dexterity in making processes. In the following section, I look beyond these more isolated studies of technique, to study a range of techniques used when prototyping and making furniture. This enables me to demonstrate how the micro-level analysis of epistemic character can be transferred into a broader context.

6.4.1. The File and The Belt Linisher

When using a hand file in a forward motion (a technique known as cross filing) the teeth of the file travel roughly perpendicular to its motion, cutting away material as the tool is pushed away from the practitioner. Repeated passes are used to progressively remove material. The file's teeth cut only in this forward direction so, to avoid prematurely dulling their edge, the file is raised at the end of each pass and returned to the starting point (Figure 6.7). As the file is pushed, lifted and retracted, the back and forth of the tool presents regular opportunities to see the emergent result. In the rhythm of practice, it is typical to make multiple passes with the file, glimpsing the result between each one, before pausing for a longer period to study the result in more detail. Typically, file strokes are bundled into bursts of action, with longer pauses between.

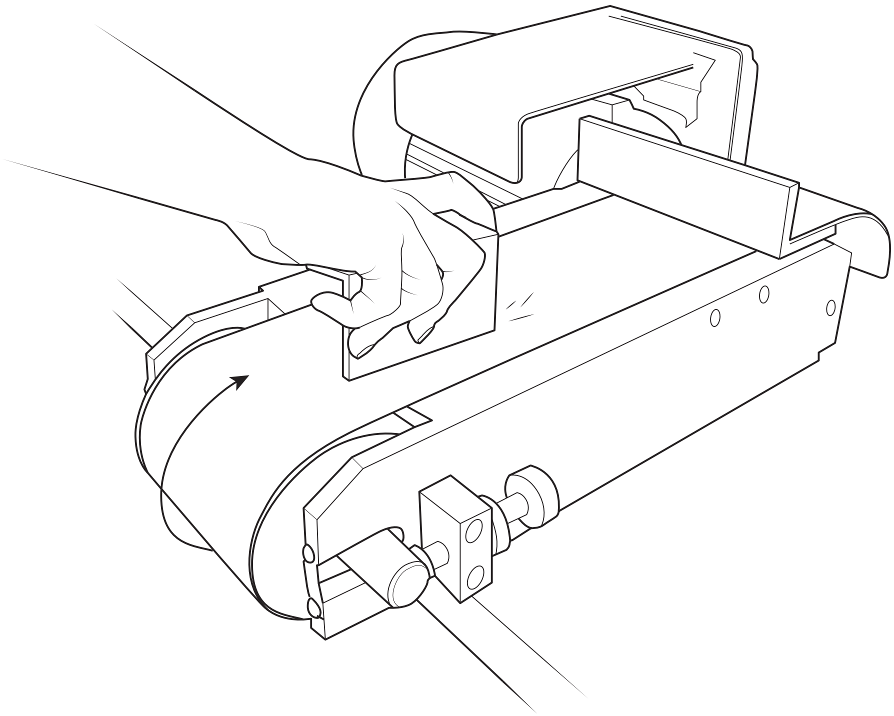
Figure 6. 7 Cross filing with a hand file



Because the file teeth will only cut to their own depth, there is a threshold level of downward pressure that, once exceeded, will make no difference to the amount of material removed by the file (this is a characteristic shared with many hand tools, e.g. saws and bench planes). If the same length of pass and a level of downward pressure beyond this threshold are used, the file removes the same amount of material with each cut. For this reason, we can be assured that each set of, for example, ten passes will allow us to reliably predict what the next ten passes might achieve.

A belt linisher, or belt grinder, can be fixed to a bench or freestanding. It uses an electric motor to drive a belt of abrasive emery cloth around two pulleys. When wasting metal with a linisher, we offer the work to the rotating belt, which removes material through abrasion (Figure 6.8). The belt is driven at a constant speed, and consistently removes material for as long as we hold the work in place. In contrast to the bursts of rhythmic action employed when filing, the continuous pass of the linishing belt could, theoretically, waste as much material as required from a face in one go, without the work piece being removed from the machine[5].

Figure 6. 8 Using a belt linisher



The step-character of linishing does not, therefore, share filing's rhythmic nature. The only interruptions to the otherwise continuous nature of the technique come about if the work piece, subject to the friction of the abrasive belt, becomes too hot to hold and must be quenched; or if the practitioner chooses to check the progress of the job. There are no routine pauses in progress—the correct time for these checks must be determined by a practitioner's own judgement. Linishing thus has a step-character that does not include regular intervals for the evaluation of an emergent result. Contrasted with the rhythmic back and forth of hand filing, the step character of linishing does not distribute decision making in regular, step-by-step intervals.

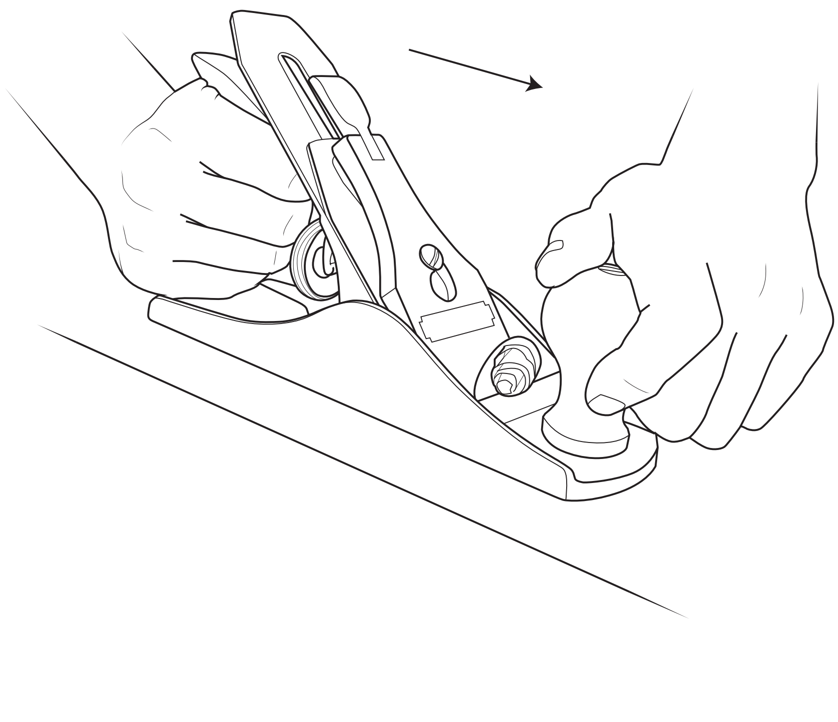
[5] A further observation about these two techniques relates to our engagement with the emergent result throughout. When filing, the work piece is typically held firm in a vice and we file a face that we can see. The emergent result is frequently visible throughout the action. When abrading a part on the belt linisher, the face we are working is not visible through the action, as we present it towards the belt, and away from ourselves. The physical arrangement of these two techniques thus differs in the access it offers to the emergent result.

6.4.2. The Bench Plane and The Thicknesser

Having introduced the relationship between step-character and the distribution of decisions, I now aim to demonstrate how it may be illuminated with reference to the models of wayfaring and transport.

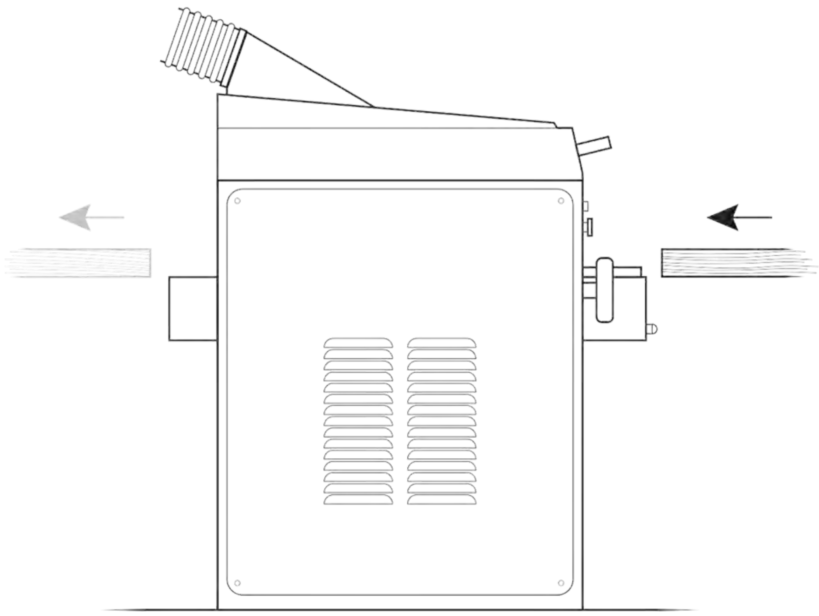
A bench plane (plane) (Figure 6.9) and a thicknesser (Figure 6.10) can both be used to waste wood from a surface. Usually, these tools would be used once a piece of wood has been resawn to slightly larger than its eventual thickness[6]. A plane or thicknesser can then be used to remove the rough surface left by sawing, and finish a piece of timber with more control than the saw offers.

Figure 6. 9 Using a bench plane



[6] Resawing is a type of rip cut, where the saw blade cuts parallel to longest face of the board. It is a cut that makes a board of timber thinner.

Figure 6. 10 A thicknesser



Depending on the required quality of the finished surface, it might be that a practitioner would always choose to work the board with a bench plane. In cases where tear-out would be unacceptable, the advantage of using a plane is that it can be readily adjusted, and its direction of attack varied to allow for inconsistencies in the grain direction. A bench plane thus enables a finer finish to be achieved more consistently than when using a thicknesser. This capacity can be understood as a practical reason why, despite the ease, speed and accuracy with which a powered thicknesser can dimension a board of timber, bench planes remain useful pieces of equipment[7].

Having identified these relative merits of the tools, however, it is important to note that this kind of reasoning is not relevant for the current consideration of their epistemic character. Whist it might be an important component of a practitioner's knowledge, the ability to create a tear-out free surface has little to do with how techniques distribute decision-making throughout a process. My investigation of these two techniques, therefore, looks not at the results that can be achieved, but at the questions asked along the way.

I interpret the epistemic character of the plane and the thicknesser with reference to Ingold's distinction of wayfaring and transport. In order to clarify the reasoning behind this

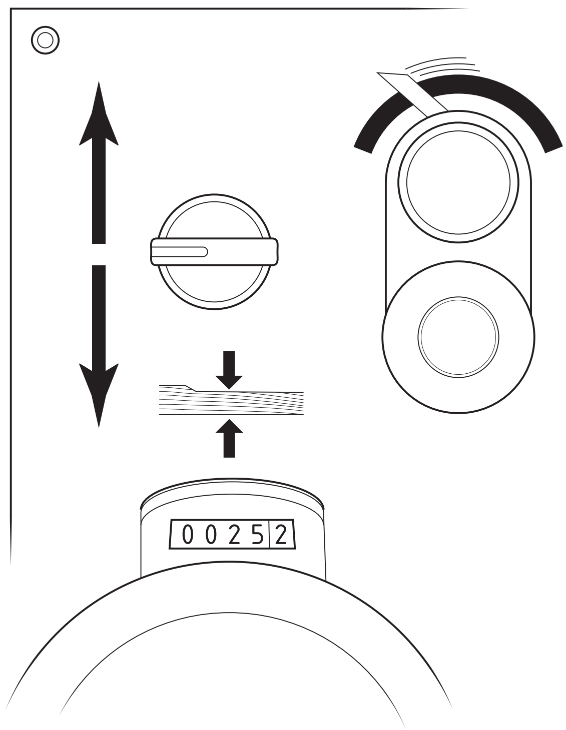
[7] It is quite common to combine the two tools in an operational sequence—by wasting the majority of the surface using a thicknesser, before finishing it with a bench plane.

interpretation, I first present a flawed attempt at this kind of analysis. I believe the second, more successful approach, then opens up an interesting area of enquiry, regarding the influence of “dexterous wayfaring” on the distribution of decisions.

A Flawed Attempt

The thicknesser asks us to specify a dimension (in mm or inches), before feeding our full board of timber into the machine (Figure 6.11). The bottom face of the board is pushed down onto the machine bed, as a rotating blade removes wood from the whole width of the top face. This makes the two faces parallel. Once the board has been ejected from the rear of the machine, we can check the result. If we wish to remove more material, the dimension is reset and the board fed through again. The amount of material it is possible to remove with each pass depends on the species of timber being worked, the width of the board, and the sharpness of the machine’s blade. A typical amount for the kind of machine shown in Figure x would be 1-2mm per pass.

Figure 6. 11 Thicknesser adjustment interface



Using a bench place, we are not asked to specify the dimensions of a result before we begin. We may work without a specific destination, taking shavings and evaluating the result with each pass. If we aim to remove a large amount of material (≈1mm), we can start by working diagonally across the grain. Cuts in this direction break the weaker bonds between wood fibres, so that the plane can be set to take a deeper cut, without getting stuck. Although this strategy results in a rough, often undulating surface, a subsequent phase of shallower cuts made parallel to the grain can be used to smooth it out. At all stages, each pass of the plane is made in response to the emergent result. With experience, it is even possible to distinguish between the sound of a plane cutting with, or against, the grain. The direction of travel and the skew of the tool is continually adjusted, to reduce effort and control the quality of the surface finish.

On the basis of this information, we might infer that the character of the thicknesser aligns to the model of transportation, and the bench plane to wayfaring. Each pass through the thicknesser asks us specify our destination in advance. Each pass with the plane is a step towards a destination, but there is no requirement for this to be determined in advance of practice. The question, "how thick would you like this to be?", as posed by the thicknesser, could be interpreted as a transport-like insistence on pre-determination. And the comparative lack of such a question when using the plane, could be seen to characterise it as a tool of the wayfarer.

On reflection, however, I find this to be relatively weak justification for characterising the processes in this way. I suggest we may interpret the technique of a thicknesser differently. Although we are asked to specify a dimension with each pass, it does not necessarily follow that we must know the ultimate thickness in advance. We are given the opportunity to assess the result after each cut. We could, therefore, work not towards a pre-determined size, but incrementally, according to an evaluation of the emergent result. Although it collapses the rhythmic progression made with a bench plane into a single (almost instantaneous) pass, the step-character of the thicknesser does offers chances for assessment along the way. The technique is, therefore, not entirely transport-like.

6.4.3. The Dexterous Wayfarer

Moving beyond this first attempt at a characterisation of the techniques, I suggest there is more to be said. Although the previous investigation is indecisive, I believe there are other features of these two techniques that do cast them, more surely, into the modes of wayfaring or transportation. These become apparent as we consider some of the other questions posed by the tools. And, as I hope to show, their discussion offers an insight into the broader subject of the value of "dexterous" tool use.

Before asking us to specify the dimension of our board in millimetres, the thicknesser has already asked a series of other questions; "Is that board long enough? I'll only accept it if its longer than the distance between my two rollers, otherwise it will get stuck"; "Is that board narrow enough? I'll only accept it if it's less than the width of my blade."; "If you're trying to thickness a glued assembly of multiple pieces of wood, does all the grain run in the same direction? And is it all flat to a surface? If not, I can't help you."[8].

It is with reference to questions such as these that we see the more significant influence the thicknesser has on the distribution of decision making. The certainty and pre-determination associated with a machine like a thicknesser are made possible only by concentrating decision-making into a specific point in time. We can only use the machine to thickness pieces of timber when they are long enough and narrow enough. If we are working with an assembly, all parts must lie flat to a surface, and their grain must run parallel (as in, for example, a table top). If these conditions are not met, there is no action (and therefore no thinking) that can be supported by the thicknesser.

The bench plane, by contrast, can be used to waste the surface of an emergent result in many more situations. The only prerequisite of plane use is that the work can be held firm, either in a vice, or by another means. With a bench plane wielded in mid-air—unconstrained by the determining arrangement of a machine tool—no surface need ever be considered "finished". "Would you like to take a shaving off that?", "How about a chamfer on that edge?", "Do you think that leg should be tapered?" These are decisions that could be made at any stage of production (or even later on, throughout an artefact's life).

This characteristic of the bench plane brings us back into line with Ingold's account of wayfaring. '[T]he wayfarer', he writes, 'has no final destination, for wherever he is, and so long as life goes on, there is somewhere further he can go' (p.150). I suggest this aspect of wayfaring offers a useful insight into the epistemic character of dexterous tool use.

Take, for example, the hand saw of Ingold's study. When cutting across a board, the result becomes determined after just a few strokes. Comparing the same operation, as performed using the powered crosscut saw, I have suggested that we find little difference in the distribution of decision-making. But, looking at the technique of hand saw use more generally, we find the same characteristic as with the bench plane. Even a fully-assembled

[8] I appreciate this anthropomorphic approach to a machine tool is quite odd. In my defence, I defer to other examples, previously discussed, that use the metaphor of "conversation". Or, if it helps, these questions could also be understood as affordances (see 5.1.1).

furniture prototype could be modified. “Are the legs a bit long?”, “Should that bit be cut flush to the others?”, “Could we get away with less of an overhang?” The value of dexterity to the wayfarer is that it distributes decisions so that they can be made over a longer period, with reference to an emergent result. Things can be finely adapted. We can work in mid-air.

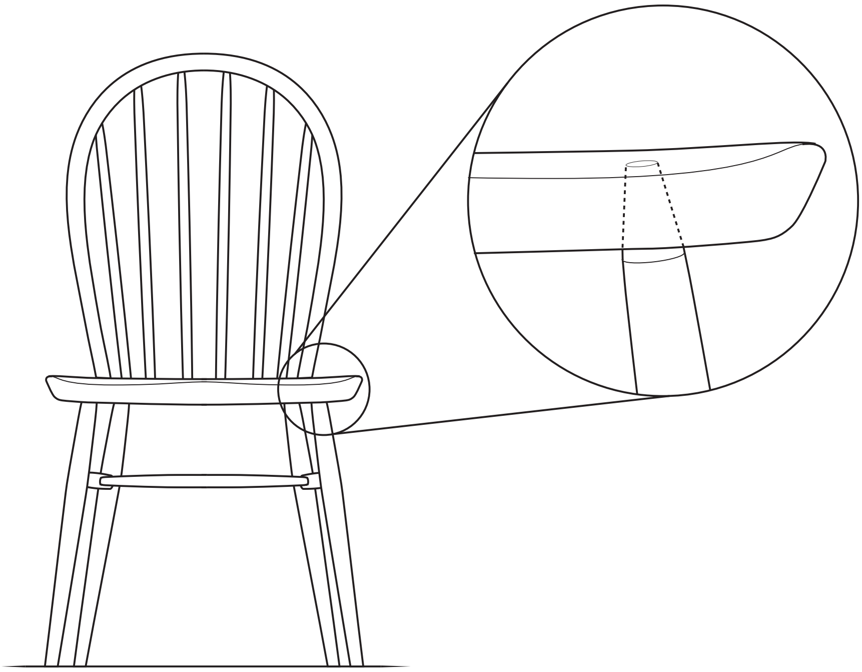
6.5. Prototyping Staked Furniture

In this final study of distributed decision making, I build out from the localised study of techniques, by looking into the context of furniture prototyping.

As defined by woodworking writer Christopher Schwarz, “staked” furniture is ‘made up of a thick platform of wood that is pierced by its feet’ (2016, p.29). Whilst historically used to make all kinds of furniture—including tables, desks, beds, stools, and workbenches (ibid., p.19)—staked construction techniques are today most often seen in Windsor chairs. The seat of a Windsor chair is pierced by the legs from below, and by the backrest, spindles and arms from above. The structural integrity of the chair relies on the thickness of the seat, and the fit of the joints used to attach the “stakes”.

Whilst the joints of staked furniture can be made with straight-sided cylindrical tenons, it is more common to use a tapered (conical) mortice and tenon (Figure 6.12). This increases the strength of the joint and makes assembly easier (Galbert 2015, see p.18). The tapered mortice and tenon also plays a key role, as I describe below, in the distribution of decision making throughout the design and construction of staked furniture.

Figure 6. 12 Windsor chair with tapered mortice and tenon detail



6.5.1. How to Make a Tapered Mortice and Tenon

To make a tapered mortice, we first drill a hole with a straight drill bit (Figure 6.13), before using a reamer to taper the walls of the hole (Figure 6.14).

Figure 6. 13 Drilling a mortice

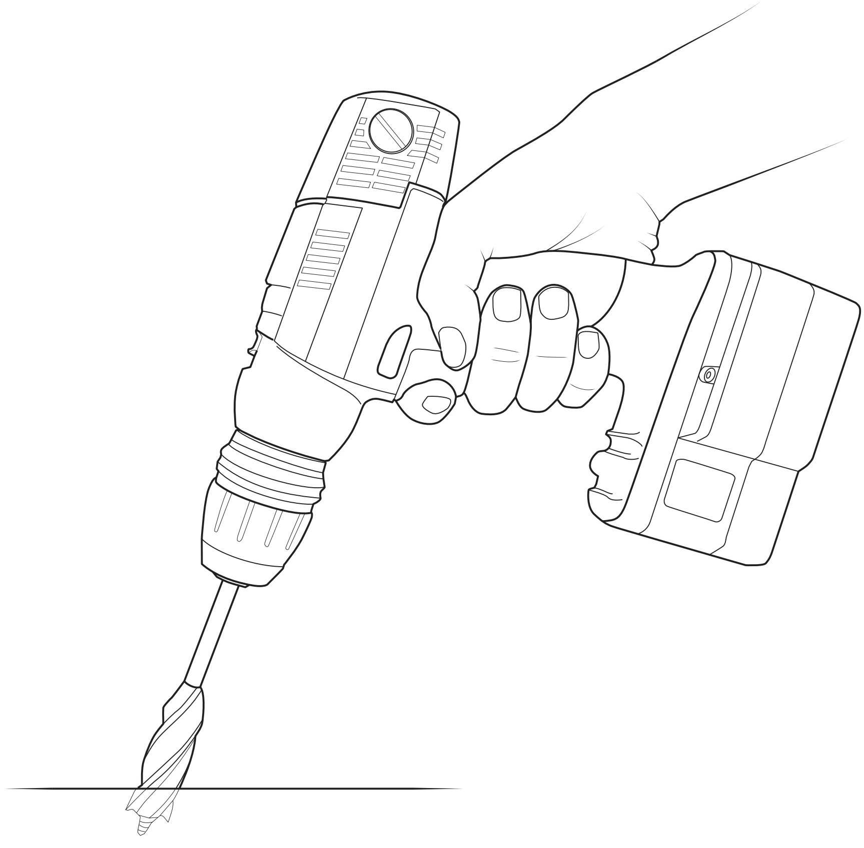
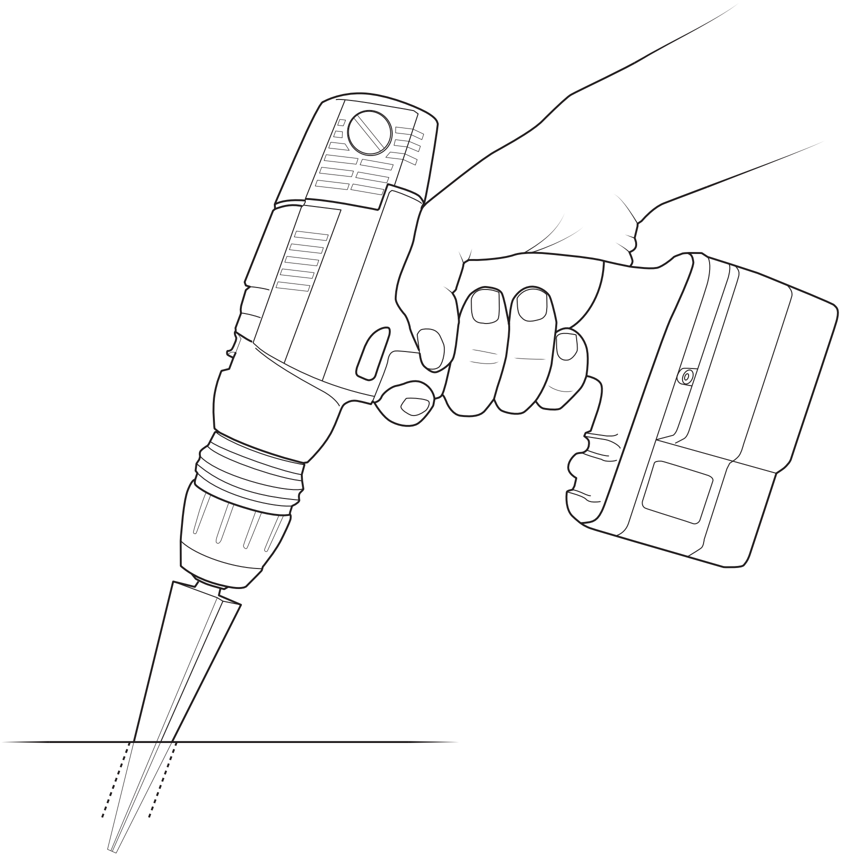
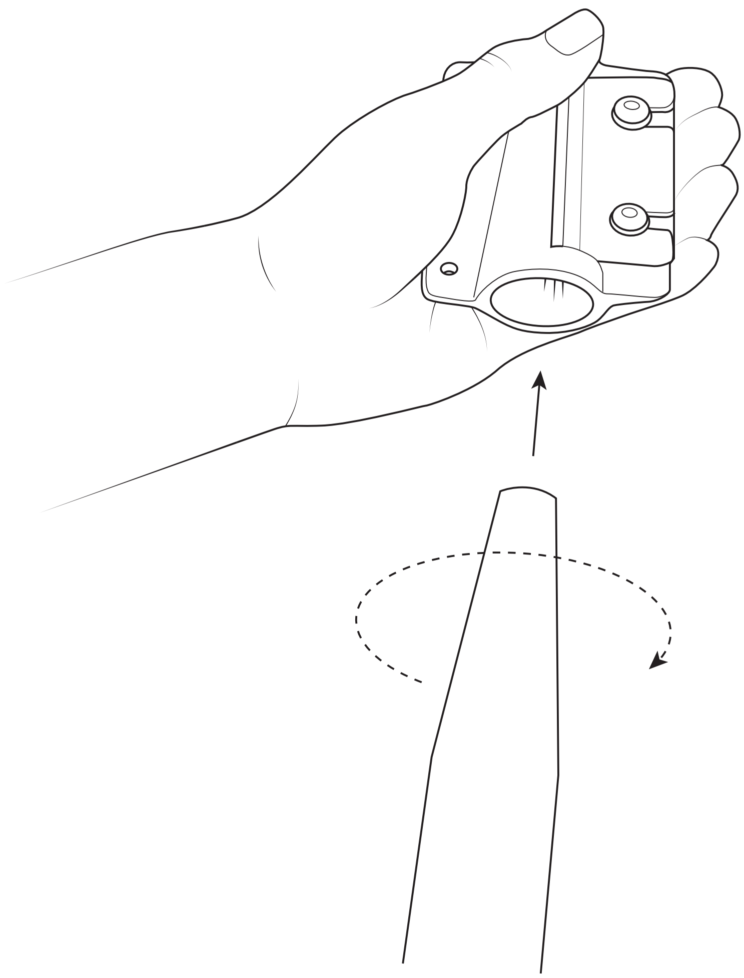


Figure 6. 14 Reaming a mortice



The corresponding tapered tenon may be turned on a lathe, shaped by hand using a spokeshave, or (perhaps most conveniently) created using a dedicated taper tenon cutter (Figure 6.15). This is like using a large pencil sharpener. The angle created by the tenon cutter should correspond to the angle of the reamer used to taper the mortice.

Figure 6. 15 Using a taper tenon cutter

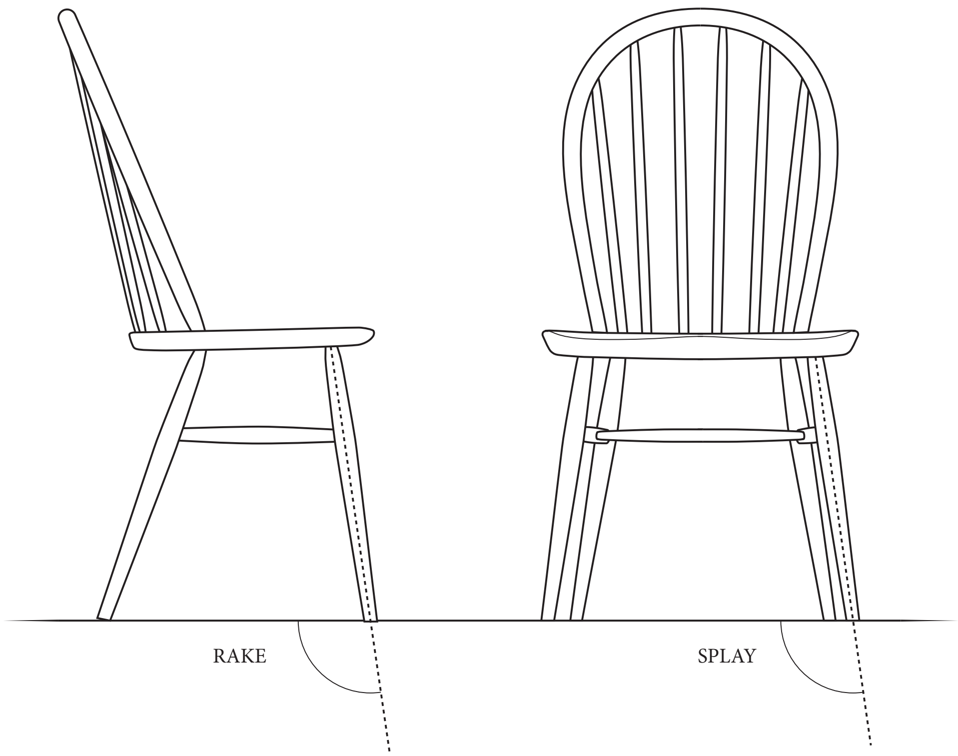


Before describing how the tapered mortice and tenon helps to distribute decision making throughout the design and production of furniture, I introduce some prototyping techniques. This should help to illustrate some of the considerations influencing the design of staked furniture.

6.5.2. Wire Models

The legs of staked furniture are usually angled in both the horizontal and vertical plane. This ensures the mortices can be drilled well inside the edges of the seat (or other "platform"), whilst still creating a stable footprint at ground level. In chair making, the angles of the legs are known as the 'rake and splay' (Schwarz 2016, p.44). The rake is the angle of the legs to the seat when looking at the chair from the side, and the splay is the angle of the legs when looking at the chair from the front (Figure 6.16). Because neither the rake or splay of a typical piece of staked furniture is 90°, the legs usually meet the seat at a compound angle.

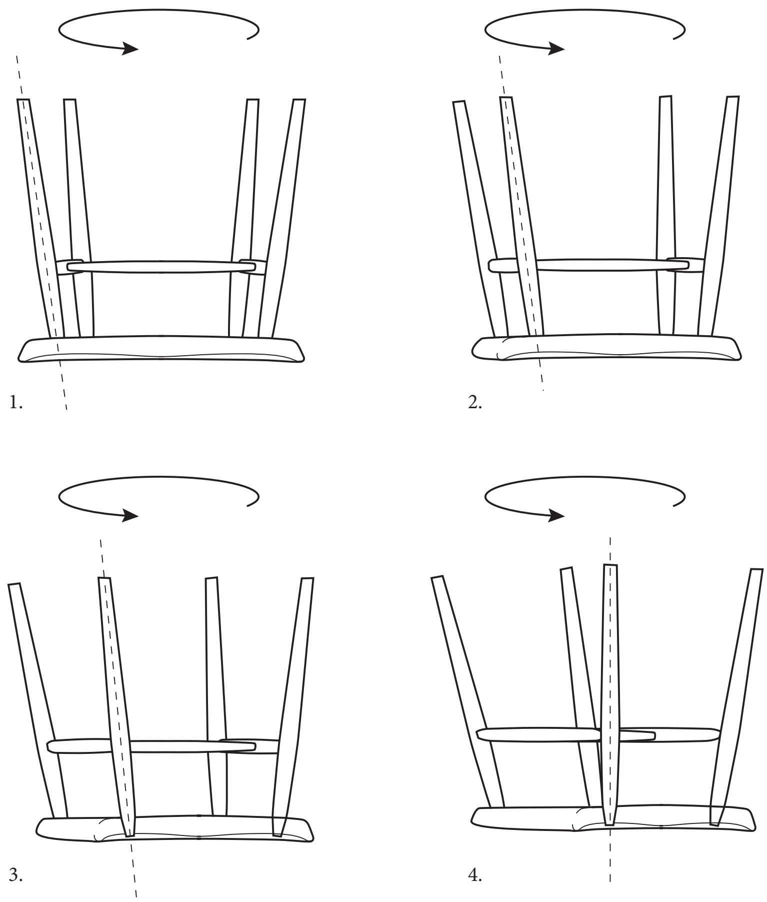
Figure 6. 16 The rake and splay angles of a Windsor chair



Dealing with compound angles in joinery can be difficult. Cutting or drilling at a single angle relative to the edge of a workpiece (like when cutting a mitre at 45° for a picture frame) is relatively straightforward. If that cut needs to also be angled in the other plane, however, it becomes more challenging. In the context of designing staked furniture, this means that the transition from two-dimensional drawings (like Figure 6.16), to a three-dimensional prototype is more complicated than it would be with non-compound joinery.

The key to overcoming this challenge is to find the 'resultant angle' and its associated 'sightline' for each leg (ibid., p.47). Through working out the resultant angle and its sightline, we effectively turn our compound angle into a single angle. This is achieved by finding the viewpoint from which the leg appears to be vertical—a process best described using illustrations (Figure 6.17).

Figure 6. 17 Rotating a chair to find the sightline



In Figures 6.17 we see the undercarriage of an upside-down, completed chair. As the leg and seat are rotated throughout the series of illustrations, we see the leg come into alignment with the vertical. At this point we are looking at the leg along our sightline (Figure 6.18). The resultant angle is the angle of the leg, as measured along this sightline (Figure 6.19).

Figure 6. 18 The sightline from above the upside-down chair

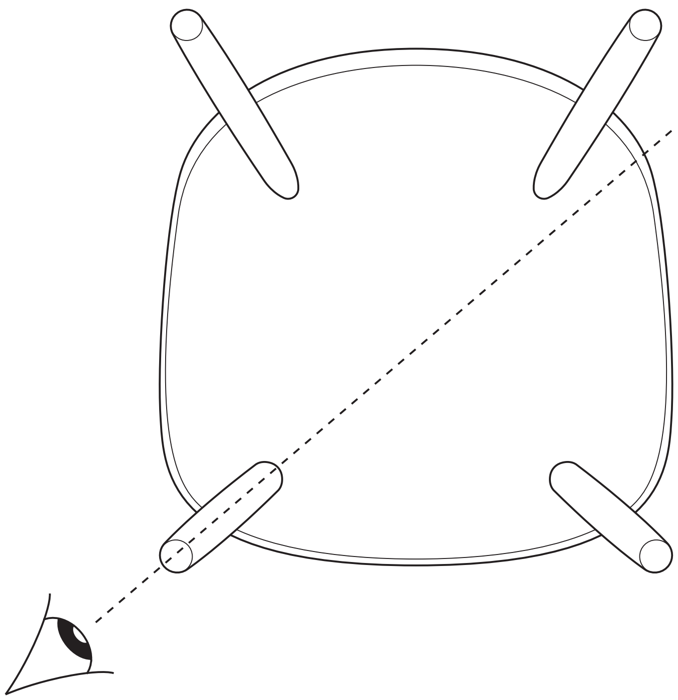
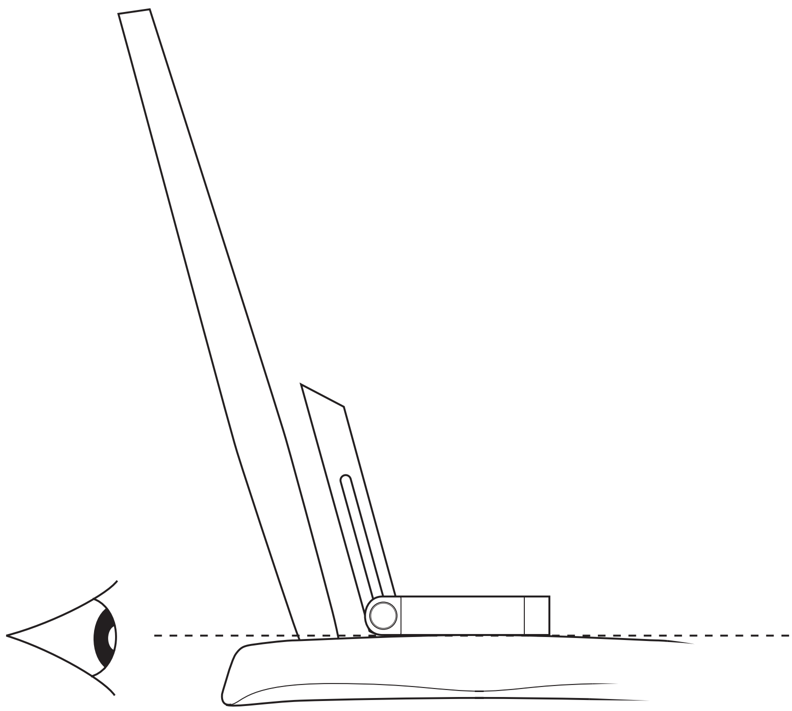
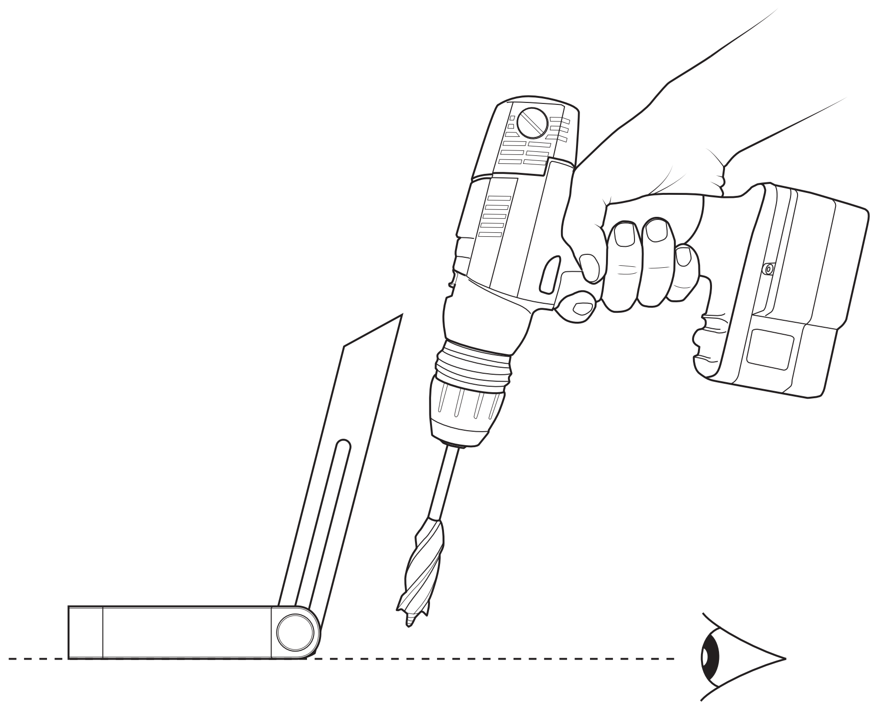


Figure 6. 19 Measuring the resultant angle



If we were working on an uncompleted chair, this process of discovering the sightline and resultant angle relies on us manipulating and measuring a three-dimensional model. Whilst it is possible, as described by chair maker Peter Galbert, to calculate sightlines and resultant angles from the rake and splay angles of two-dimensional drawings, (2015, see p.356), Schwarz recommends the use of wire scale models (approx. 1/5 scale) throughout this process (2016, p.48). This allows us to evaluate the compound angle in three-dimensions, and quickly reposition the malleable wire to make amendments. Once happy with the angles of the model, we can then find its sightlines following the process described above, before measuring the resultant angles with a sliding bevel. Sliding bevels can be locked to match these resultant angles, and then used as a guide to drill the mortices of a full-sized prototype (Figure 6.20). Despite the apparently complex compound joinery achieved throughout this method, Schwarz describes a design process that can be performed without any reference to numbers.

Figure 6. 20 Drilling the resultant angle

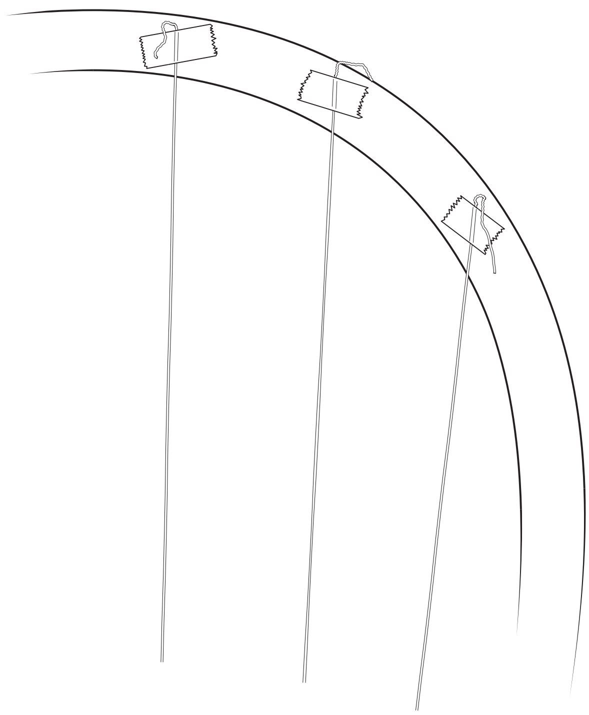


6.5.3. String and Cardboard Tubes

Further to Schwarz's model-making approach to staked furniture design, I now discuss another two prototyping strategies I have developed.

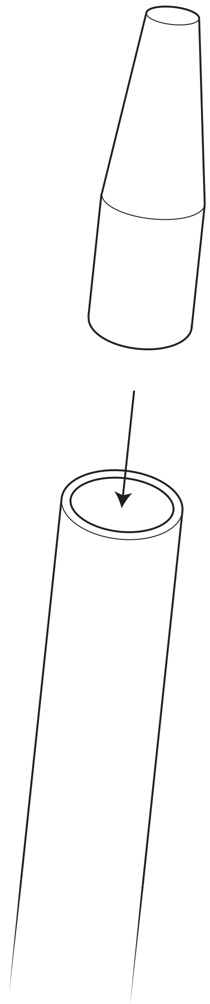
One of these strategies is to use string and brown tape to decide upon the number of spindles in a chair back, and their spacing (Figure 6.21). The convenience of using string in this way is that it does not need to be cut to an exact length (excess can just be taped up), and it can be readily repositioned when evaluating alternatives. The string, like the wire of Schwarz's models, is representative of what will become a part of much larger diameter. Its use is directed towards deciding upon the general arrangement of the spindles. The diameter and form (be they tapered, straight or otherwise) of the spindles, is a decision to be made later, perhaps with reference to cardboard strips, cut out to create a silhouette and taped to the string. This is a relatively straightforward instance of "incremental decision making" being supported by techniques.

Figure 6. 21 Using string to work out the spindle arrangement



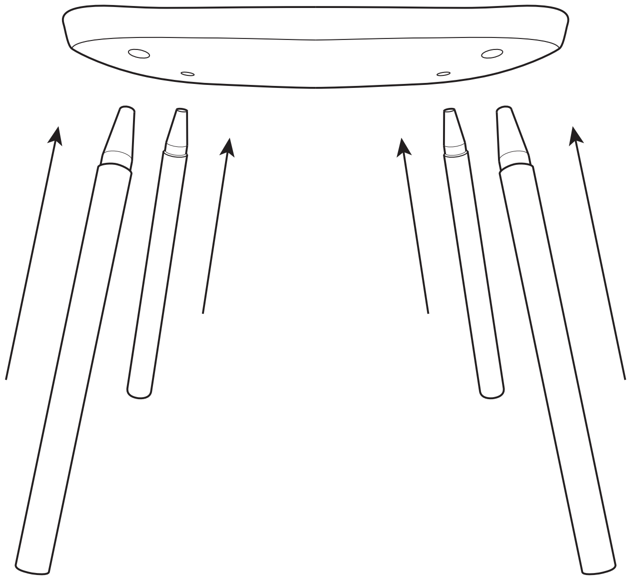
Another strategy I have developed is to use one inch (25.4mm) diameter cardboard tubes to test designs for the undercarriage of a chair. Combined with a collection of tapered wooden inserts (Figure 6.22), these tubes enable the kind of experimentation Schwarz performs with his wire models, but at full-scale. The wooden ends are made to fit tightly into the ends of the cardboard tubes, and can be taped in place for reinforcement. By cutting up lengths of tube, and adding the tapered ends, we can quickly create four legs of any length.

Figure 6. 22 Cardboard tube and tenon insert



A board of plywood, MDF or scrap wood can then be cut to the anticipated shape of our seat and drilled from underneath, to accommodate the tapered legs (Figure 6.23). For a tenon that tapers from 12mm at its point, up to a diameter of 19mm, a drill size of roughly 15mm would be appropriate.

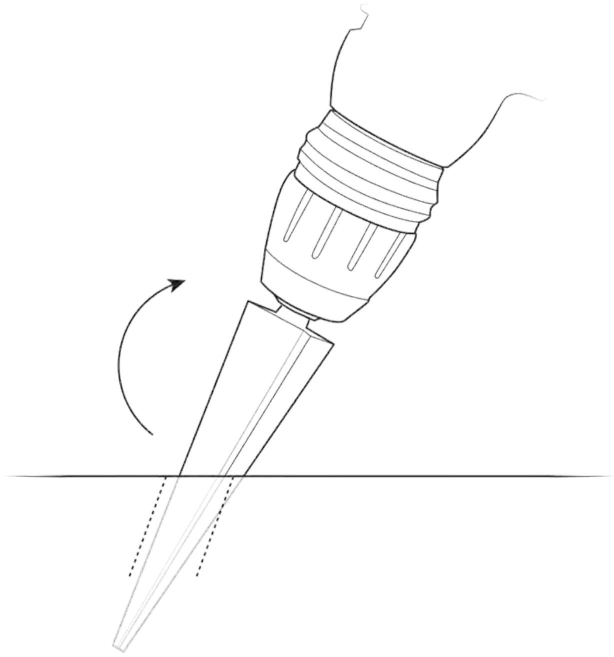
Figure 6. 23 Cardboard tube legs and a prototype seat



It is once these holes are drilled that the advantage of the tapered ends becomes apparent. In our temporary seat, we do not need to ream the drilled holes to match the taper of the tenon. Whist it is important to drill the holes at (roughly) the correct angle, the taper will centre itself in the hole, whether it is reamed or not. We won't be gluing the tenon in the hole, so we do not need to be concerned by the lack of contact area inside the joint. This method also gives a little play in the joint—enough for us to wiggle the tenon and adjust the angle by a degree or two, so that we may evaluate fine adjustments to the rake and splay.

If we are unsatisfied by the position of the legs, it is very convenient to drill some new holes under the same seat. If we are happy with the legs' position, but not their angle (even once wiggled), we may use the reamer to modify the angle of the hole (Figure 6.24). Just a few turns can be used to adjust the angle—it is best to proceed cautiously, checking progress regularly by replacing the cardboard leg. A variety of leg positions and angles can be quickly trialled in this way.

Figure 6. 24 Modifying a mortice angle with the reamer



Once the legs are in position, we may turn to our attention to the stretchers—the parts that run between the legs. These can also be created using cardboard tubes and wooden ends. Before committing to drilling the holes in the cardboard legs, we can use string (as when thinking about the spindles) to determine their position (Figure 6.25). The string then acts as a visual guide to drill the hole in the correct place (Figure 6.26). Once drilled, the cardboard stretcher can be cut to length[9] and slotted into place.

[9] By sliding the wooden ends of the stretcher in and out of the tube, we can adjust its length slightly. The length that the stretcher tubes are cut to is thus non-critical.

Figure 6. 25 Using string to work out the stretchers

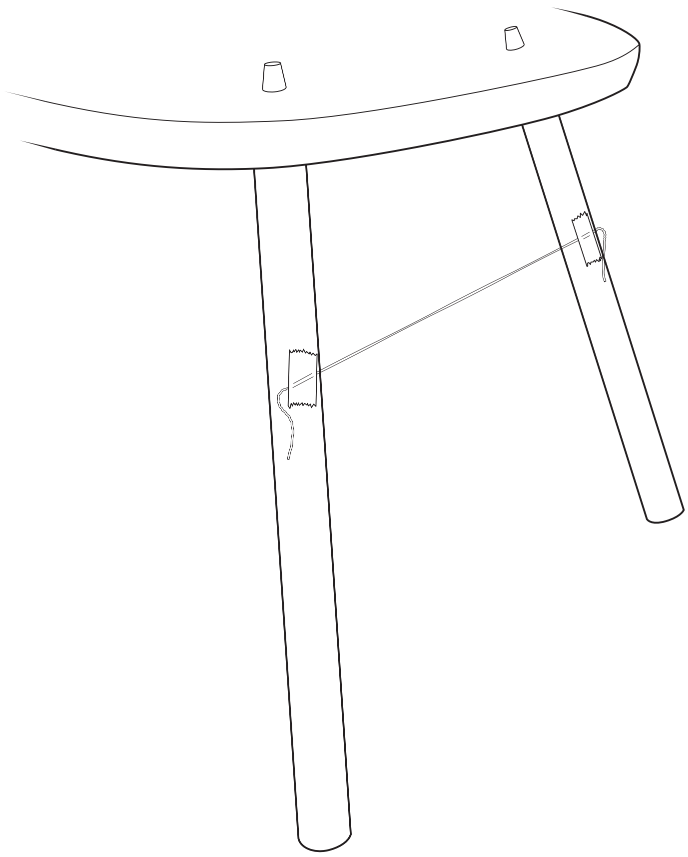
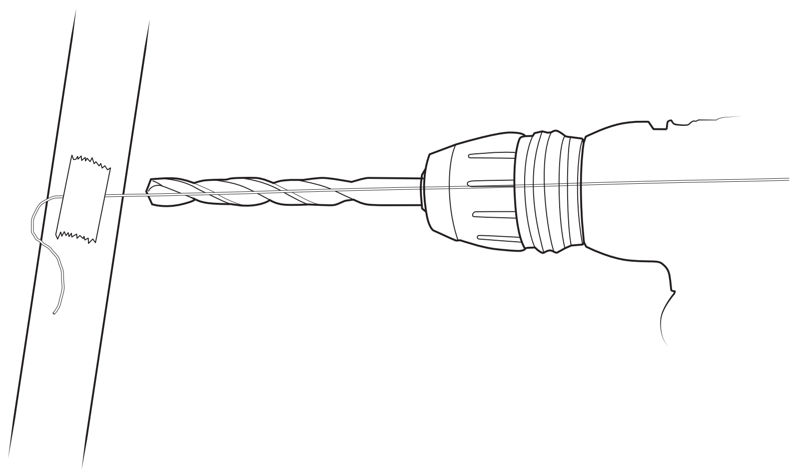


Figure 6. 26 Drilling in alignment with string



6.5.4. Cardboard and Drawings

It should be noted that prototyping furniture using the techniques described here is quite different to designing furniture through drawing. And this is not simply related to the differences in evaluating a paper or screen-based result vs. evaluating a three-dimensional one. It can also be considered in terms of how the prototyping techniques distribute decisions.

Through the production of our cardboard tube models, just like when folding a paper plane (see 5.3.4), we are making decisions about proximate goals, not overall ones. Our attention is always focussed on the technique in hand. When taping up the string “spindles” we are concerned with their spacing. When cutting out the cardboard “spindle silhouettes”, we are thinking about their form. When working out the stretchers, we have already determined the legs. We are, to borrow Alexander’s metaphor, flipping one coin at a time.

In the practice of designing a chair through drawing, the process is not structured in the same way. We need not work in any particular order, or have our attention focussed on any particular features. With each sketch, we are free to flip as many coins as we like. I appreciate that this aspect of representational practice can have its rewards. Chief amongst these, according to the literature, is the ability to make ‘lateral transformations’ (Goel 1995, p.119) between different ideas whilst making a ‘relatively unstructured and ambiguous sketch […] early in the process’ (Purcell and Gero 1998, p.389). In the later, less explorative and more experimental[10] stages of design practice, however, I would suggest, along with Alexander, that some techniques can *structure* the decision-making process in a positive way.

6.5.5. A Model of Distribution

I developed these strategies for prototyping staked furniture because they are useful in their own right[11]. But using these techniques, and subsequently making the furniture that was prototyped, has also made me aware of the inherently distributed character of designing and making using the tapered mortice and tenon joint. As described above, it is a joint that allows for revision and adaptation throughout the prototyping process. I suggest it distributes

[10] I take this distinction, between exploration and experiment, from Gedenryd (1998, p.123-30).
[11] I have found these strategies particularly useful when working with students to help them develop designs.

decision making in the following ways, whether making a prototype or a "real" piece of furniture;

- The taper is self-tightening, allowing even an unglued piece of furniture be tested. When designing and making a chair, for example, we can sit on it, decide upon revisions, dismantle the assembly and make those changes.
- As in the cardboard tube prototyping process described above, there is an opportunity for revision between drilling the straight hole of our mortice and then reaming it. Even at a late stage in production, the angle of the legs can be adjusted.
- It is a simple and convenient task to shorten any of the legs or stretchers, by wasting more material from the tenon, using the taper tenon cutter (the "pencil sharpener"). This is unlike re-cutting a conventional tenon (with sawn cheeks and shoulders), which would be a time-consuming job.
- The process of laying out and fitting the stretchers is both technically easier and better supported with reference to the emergent result if it is done after the legs have been dry-fitted. We are therefore asked to distribute these decisions throughout the process.

I suggest that this adaptability and distributed decision making is what makes the Windsor form particularly suited to the use of green wood, when produced in low-volumes. Where other furniture making techniques would struggle to accommodate the lively characteristics of wood with a high moisture content, chair makers like Peter Galbert are able to exploit the favourable properties of green wood to significant advantage[12].

Critical to this effort is the possibility for adaptation in response to the emergent result. As described by Galbert, strict adherence to a prior specification would risk 'telegraphing' errors throughout the chair (2015, p.16). 'Instead of trying to make each part fit numbers on a drawing', he writes, 'I make it to fit the chair' (ibid., p.17). This is an approach made possible by the techniques of Windsor joinery.

Before moving on, there is one additional advantage to the tapered mortice and tenon. Making a chair to the high standards of Galbert's work obviously requires a great deal of experience. But where our joints fall short in their accuracy, Schwarz advises us, on the

[12] By splitting out parts from a log, for example, Windsor chair makers are able to create spindles that follow the grain. Because they are not weakened by any grain run-out (see 5.2.2), these spindles may be thinner (more "spindly") than non-green alternatives, contributing to a lightweight chair (both physically and visually).

evidence of historical examples, to '[t]ake a little comfort from the fact that even imperfect conical joints can last for centuries' (2016, p.66).

6.6. Sundqvist's Simple Tools

Having discussed examples of how epistemic character influences the distribution of decision making, I now return to the claim made by Wille Sundqvist;

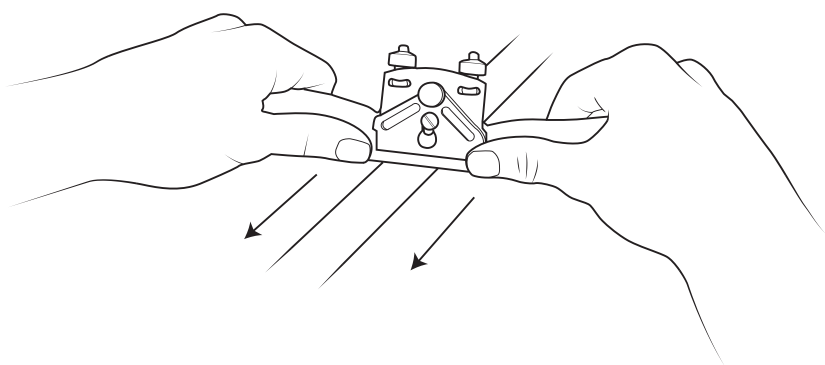
> 'A sense of design that comes from using simple tools cannot be had from machines' (1990, p.106)

Whilst I agree that there is a validity to Sundqvist's claim that different tools (and their associated techniques) might affect our "sense of design", I suggest that the dichotomy he describes between "simple tools" and "machines" is misguided. And I offer one more short comparison to help interrogate Sundqvist's position. Both techniques could reasonably be used in spoon making.

6.6.1. The Spokeshave and The Coping Saw

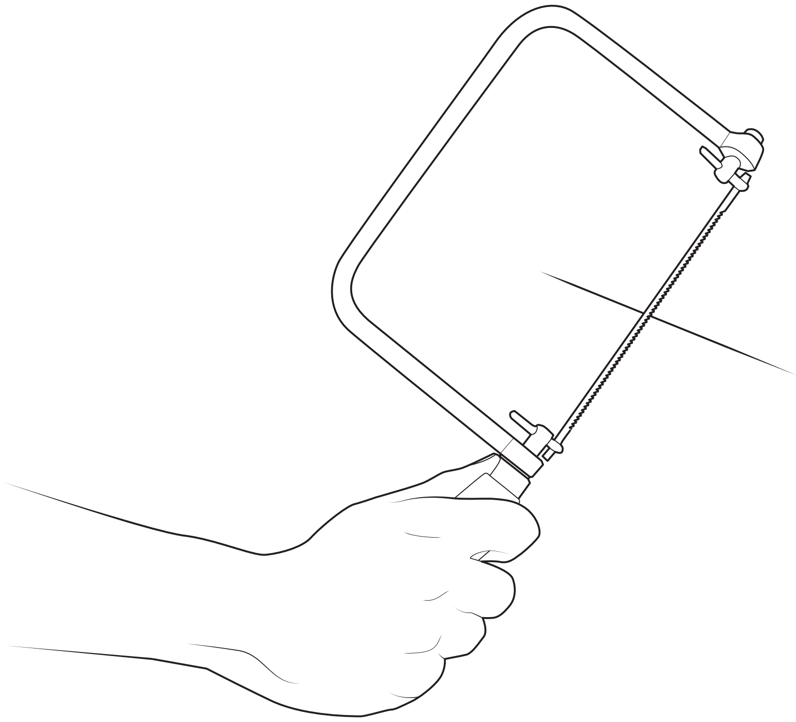
I suggest that both a spokeshave (Figure 6.27) and a coping saw (Figure 6.28) could, along with the axe of Sundqvist's quote, be considered "simple" tools. It would be unusual to describe either tool as a "machine"[13]. But, despite both employing "simple" tools, the techniques of spokeshaving and coping sawing distribute decision making very differently throughout a process.

Figure 6. 27 Using a spokeshave



[13] Both tools are, for example, included in Aldren Watson's book *Hand Tools: Their Ways and Workings* (1982).

Figure 6. 28 Using a coping saw



The epistemic character of coping sawing, I suggest, has more in common with using a powered band saw than it does with using an axe. As I discussed with reference to Ingold's handsaw, the technique of sawing asks us to concentrate decision making in advance, without reference to incremental feedback. We might draw a line on the timber in advance, or make the cut without any guidance. Either way, the result only emerges with the last stroke, as all the waste wood is removed simultaneously.

Using a spokeshave by contrast, wasting can proceed by small steps, in increments determined by the maximum thickness of shaving the tool can take. The nature of spokeshave use thus sees a woodworker presented with the emergent form after each pass with the tool. We may pause to check the result and make adjustments if required. When making a spoon, like Sundqvist, or a handle of any sort (as I have described elsewhere (Luscombe 2017)), the spokeshave's incremental character allows us to refine the result until the handle becomes pleasing to hold.

To return to the distinction between transport and wayfaring, the technique of using a saw asks us to specify our destination (the eventual shape of the cut) in advance. Using the spokeshave is more akin to the experience of wayfaring.

I suggest that the "sense of design" that Sundqvist values is not a result of the relative simplicity of his axe, but of the way the technique of shaping with an axe structures the process of designing and making. It forces us to proceed incrementally towards a form, where the bandsaw asks us to determine it in advance. This is not a character inherent to the tool itself. As we have seen when splitting a piece of timber with an axe (see 5.2.4), the result is predetermined as soon as the split begins, according to the grain running through the wood. In this case, the same tool does not offer the same sense of design.

6.7. Summary

Philosopher Beth Preston considers the modern obsession with planning to be a 'false ideal' (2013, p.43). Despite the obvious failings of what she calls the 'centralised control model' (ibid., p.30) of behaviour, Preston wonders, why are we 'constantly prompted to do more and better planning in every area of endeavour from the personal to the public?' (ibid., p.43). This is, I suggest, the same sentiment we find expressed in Christopher Alexander's 30 coin experiment. Alexander presents a fundamentally performative approach to designing and making. I return to his work in the following chapter's "discursive contribution", and examine how, if we subscribe to his understanding of creative practice, the concept of epistemic character is highly significant.

For those less enamoured, or more skeptical, of Alexander's performative ideals, however, I believe this chapter still makes a valuable contribution to the thinking on the subject of designing and making. First, it helps to clarify the dynamic nature of risk and decision making throughout a technique. The appropriation of Tim Ingold's models of wayfaring and transport offers a novel means of describing the distribution of decision making throughout techniques. We have seen how these might be applied to practical examples and, in the discussion of prototyping furniture, shifted focus from localised instances of tool use, to consider epistemic character at a macro-level. The idea of "dexterous wayfaring" contributes a valuable perspective on the role of dexterity in creative practice. And, in the closing discussion of Sundqvist's concept of simple tools, we see how the idea of epistemic character offers a position from which we may critique long-held opinions about the difference in hand or machine tools.

7. Discussion

In this closing chapter, I first restate my contributions, alongside a brief description of where I believe they are evidenced throughout the thesis. This is followed by a section discussing the limitations of research, and possible future work. I then go on to offer an additional "discursive contribution". This is an extension of the ideas introduced in the last chapter. Drawing on the work of Christopher Alexander, I suggest that the ways in which techniques distribute decision making might have an important impact on the quality of our environment. I describe this as a "discursive contribution" because it is suggestive of what I believe to be the full value of my research, but I recognise it is not yet comprehensively argued. In summary, I identify Alexander as an "artisanal architect"—someone who takes the ideas of emergence and performativity not just as ways of describing practice, but as *best practice.* The "30 coin experiment" of the previous chapter introduced this approach. I describe his work here in more detail, in order to discuss its potential affinity with my concept of epistemic character. I then end by returning to the work of David Pye. I hope to show how Alexander's thinking, combined with the idea of epistemic character, can help to usefully re-evaluate Pye's concept of "diversity".

7.1. Restatement of Contributions

1. I have presented an argument that recasts the making process as a means of thinking, rather than merely transcribing antecedent ideas. I have drawn on literature from disciplines where this argument has been well-rehearsed, and contributed a novel synthesis of existing ideas in terms relevant to design studies and practice.

This idea is fundamental to the whole thesis. Whilst I developed this theoretical commitment chiefly throughout Chapters 2, 3 and 4, I believe the subsequent studies in Chapters 5 and 6 can be seen to reinforce its relevance, significance and novelty.

In Chapters 2 and 3, I described how similar arguments have already been developed in other disciplines. And, in Henrik Gedenryd's work, I found an application of the same thinking in the context of design studies (see 3.2). The novelty of this contribution comes not from the content of the argument then, but in how I have woven together previously separate ideas to develop a useful foundation for the specifics of my study. In isolation, the points I make in Chapter 3 have already been made in a range of other sources. But taken as part of my thesis as a whole, I believe the notion of 'making as thinking' has been elaborated in a novel and valuable way.

2. I have presented an analysis of techniques that describes their simultaneously *epistemic* and *pragmatic* nature; I have defined techniques as a means by which to find out about the world and change it simultaneously.

In Chapter 4, I discussed Kirsh and Maglio's notion of epistemic action, with reference to the technique of hammering in a pin. I focused on the nature of dexterity in order to develop a foundational account of the simultaneously epistemic and pragmatic nature of tool use.

Although the term "epistemic action" was developed in the mid 1990s, and the idea of doing as a kind of thinking goes back as least as far as the philosophy of Dewey (1929), I claim that my application of this concept, to the tools and techniques of designing and making, is a novel contribution.

As I discussed later on in Chapter 6 (see 6.2), the technique of hammering does not provide an example wherein significant design decisions are being made throughout. But by recasting tools more generally as both means for getting the job done, and for sensing the progress of a task, it was in Chapter 4 that I laid the ground for the subsequent studies of epistemic character. I therefore see this idea as a transition from the theoretical concerns of the previous chapters, towards a discussion of how this understanding may be applied to practice.

3. I have presented a novel critique of the work of David Pye, according to the theoretical foundation developed in contributions 1 & 2.

Alongside my discussion of hammering and epistemic action, Chapter 4 also saw me develop a critique of the work of David Pye. This was an opportunity for me to expose some of the assumptions of Pye's work, with reference to the alternative theories described in Chapter 3. Although, as I hope this thesis makes clear, I remain an admirer of Pye's writing, I believe my criticisms are valid and, owing to Pye's continuing legacy, a valuable contribution to both design and craft theory.

Where Chapter 3 developed a general, broad-based discussion of non-dualist approaches to designing and making, my specific discussion of Pye's work was intended to present the case in a more digestible and relevant format (and therefore aligns with contribution 7, below). I have presented this critique of Pye in an abridged form in my paper, 'What's a Mallet For?: A Woodworker's Critique of The Workmanship of Risk' (Luscombe 2017), but would be eager to develop this topic into a more comprehensive publication through future work.

4. I have introduced the term ‘epistemic character’ in order to frame a new subject of interest—how techniques structure design processes. I have argued that we may investigate the epistemic character of techniques, and I have provided examples of how such investigations may be pursued.

5. I have introduced three questions that may be asked of a technique’s epistemic character: What are the *questions posed* by a technique?; What is its *step-character*?; and what is the *nature of the emergent result*?

I believe contributions 4 and 5 to be potentially the most significant of this thesis. I think the notion of epistemic character could become a useful subject of investigation for both design theorists and practitioners. In Chapter 5, I hope to have clearly demonstrated three questions of epistemic character that may inform future studies. These were developed out of my own reflections on practice, and also according to the ideas of others (see 5.1.1., 5.2.1., and 5.3.1). They thus tie together some of the literature explored while developing Chapters 3 and 4, with my own practical investigations.

It should be noted that the concept of epistemic character relies on the preceding methodological contributions of this thesis. Where I have already published the idea of epistemic character therefore (see Luscombe 2018), I have devoted a sizable portion of the text to setting out this theoretical foundation. I believe future work in this area would need to continue in this vein—by both making the case for the general role of techniques as “extensions of minds”, and analysising the epistemic character of specific techniques.

In my paper, ‘Rulers and Dividers: A Technology of Design’ (Luscombe 2018), I have suggested, following François Sigaut (see 2.6.3), that analysing epistemic character could become the role of a “technology of design”. This technology would acknowledge that every technique has its own epistemic character—a character that influences how we work things out and, therefore, what those things will be like. Uncovering the nature of this character would, I suggest, help to inform our selection of the techniques that offer the greatest promise for a given task.

6. I have provided a discussion of how the features of epistemic character influence the distribution of decision making throughout design processes. This has offered a novel insight into historic dichotomies of hand and machine tools, as I have suggested there is a more fundamental distinction to be made, between *processes throughout which things emerge step-by-step*, and *processes in which things are planned in advance of their execution*.

In Chapter 6, I explored what I believe to be one of the most significant themes that results from investigations epistemic character—that we may address the question of how techniques distribute decision making throughout design processes. Here I developed a novel appropriation of Tim Ingold's contrast of wayfaring and transportation, as metaphors for thinking about the subject (see 6.3).

As I discuss below, in an additional "discursive contribution", the idea of distributing decision making has long-since inspired and motivated my research. This discursive contribution may be considered a more speculative extrapolation of my work, which is suggestive of a future direction for the research. I hope it may serve to clarify what I believe is the ultimate significance of the concept of epistemic character. I return to the work of two important figures throughout my PhD journey—Christopher Alexander and David Pye—in order to discuss why the distribution of decisions might play a crucial role in the quality of our environment. Although I hope to have gone some way to addressing the "so what?" question in Chapters 5 and 6, this additional contribution may offer further insight.

7. Through a distinctive, designerly subject of interest (the detailed study of design and making techniques), I have developed a means of communicating and promoting extra-disciplinary theoretical ideas in a way that is relevant for design practice.

This last contribution is supplementary to the other, more targeted contributions. I suggest the way my text and illustrations link studies of technique and theory presents the ideas of this thesis in a way that is appealing and relevant to design practitioners. Inspired by the straightforward prose and illustrative style of how-to guides (see 2.6.5), I have sought to ground my theoretical discussions in practical concerns. As I discuss in Chapter 1 (1.3), this ambition was one of the factors that influenced the unconventional structure of the thesis, which introduces ideas from other literature throughout the practice-based studies, rather than in advance. Whilst this approach has presented disadvantages (most obviously that the document and the key components of PhD research are less easy to navigate), being at the stage of now looking to publish parts of this work (or similarly themed new work), I am pleased to have experimented with this means of writing simultaneously about "practice" and "theory". In one paper informed by this PhD (Luscombe 2018), for example, I use the comparison of dividers and rulers presented in Chapter 5 (5.1) to discuss the theory of extended mind and the potential value of studies of epistemic character. Having found a way throughout the writing of this thesis to jump between the details of techniques and more theoretical concerns, I feel well prepared to communicate such work with the efficiency required of a journal or conference paper. I also believe that building these discussions around the specifics of techniques serves to convince of their disciplinary relevance, and improves the experience of both reading and writing them.

7.2. Limitations and Future Work

As described in Chapter 2 (see especially 2.6.11), the context for this research was closely focussed on the interaction between a sole practitioner and the tools and materials of practice. Whilst successful as an attempt to develop a detailed understanding of the ways in which techniques structure design processes, this methodology nonetheless excludes an important aspect of much design practice—collaboration. Having engaged with techniques at the very local level, it is now worth noting how the kinds of studies I present here might inform those performed in more complex, collaborative contexts. I also reflect on my ambitions for future work with different kinds of techniques, the increased demands that these new contexts would place upon recording methods, and the pedagogic potential of this research.

7.2.1 Collaboration

The kinds of operations studied throughout this thesis (e.g. carving a spoon, making a paper aeroplane, knocking in a pin) are of a sort typically accomplished by an individual. To effectively study collaborative practice, I expect the complexity of these tasks would need to be increased, to ensure the collaboration is purposeful. Following the lead of scholars like Edwin Hutchins (1996; see 3.2.4), it would perhaps be more appropriate to investigate a pre-existing context (e.g. a design studio, or collaborative making project), instead of creating an artificial setting and task.

Of those scholars influential during the course of this PhD, it is in Andrew Pickering's accounts of scientific practice that I find the most promising model of interactivity between things and people in collaborative contexts (see 1995; 2008; see 3.2.4 and 5.3.3). Though he does not adopt the micro-level perspective on techniques that I have, in Pickering's work, I see a positive example of how things (most often scientific instruments) can be integrated into analyses of broader contexts. In Pickering's words, the things are bestowed with agency. They do not drift into the background as props supporting human action—they resist and behave unexpectedly. Pickering himself has been inspired by the actor-network theory of Bruno Latour (2005) (see Pickering 1995, p.11), and it is perhaps Latour's insight into the importance of nonhuman actors (2005, see p.71-2) in social settings that could provide the most effective grounding to future studies of epistemic character in collaborative contexts.

In the terminology of actor-network theory, the work of this thesis suggests that techniques (or the collection of tools and materials that are brought together through techniques) would be more likely interpreted as ‘mediators’, rather than ‘intermediaries’ (ibid. p.37-40). In Latour’s work, an intermediary ‘transports meaning or force [or, we could say, a design] without transformation: defining its inputs is enough to define its outputs’ (ibid. p.39) A mediator, however, has the potential to ‘transform, translate, distort, and modify’ a force (ibid.). In the context of techniques, considering them as mediators would be to insist on their influence upon practice. In an effort to maintain the vitality of tools and techniques in and amongst a more populous setting, actor-network theory might thus provide a helpful basis for studies of collaboration.

Such an extension of the research would, however, present significant new challenges. With my one-to-one study of a practitioner and a technique, it was quite straightforward to interpret the back and forth between the two parties. The risk of attempting larger-scale, more complex studies would be that the epistemic character of a technique is obscured, or drowned out, in the crowd. It might also be that the kinds of detailed investigations presented in this thesis have a granularity that is at odds with the scale of the context. A possible solution to this latter point would, following the guidance of actor-network theory, be to avoid setting out with a ‘choice of a privileged locus where action is said to be more abundant’ (ibid. p.61-2) and instead ‘follow the actors themselves’ (ibid. p.61). This approach might see the unit of analysis shift. Instead of investigating the epistemic character of techniques, for example, it might be more appropriate to study the epistemic character of environments. Refocussing the analysis in this way would leave us with potentially valuable questions such as: *What questions does the environment pose?*; *What is the ‘step-character’ of the environment?*; and *What is the nature of the emergent result throughout the environment?* Whilst the study of environments is nothing new (see Hutchins 1995; Keller and Keller 1996), I suggest that attempts to determine their epistemic character might offer a valuable new perspective on collaborative design practice.

The role of the researcher in this sort of research would inevitably be very different. Where I have adopted the perspective of a reflective practitioner, here the researcher would be involved in a task of ethnography, with new demands placed on their recording methods (see 7.2.3) and strategies for analysis. Unlike my individual interrogation of techniques, in collaborative contexts the understanding of epistemic character might have to be built collaboratively, informed by each participant’s understanding.

7.2.2 Alternative Contexts

Throughout this PhD, I consider the development and discussion of epistemic character to have benefitted from the varied range of techniques studied. One of the intended strengths of the concept is that is broadly applicable. It may, for example, be applied both to techniques normally considered as “design techniques” (e.g. using dividers, see 5.1.5) and techniques normally considered as “making techniques” (e.g. using a belt linisher, see 6.4.1). This is part of an ambition, informed by the theoretical grounding of this research, to insist on the simultaneously epistemic and pragmatic potential of tool use.

In order to explore epistemic character in the studies presented here, I have relied on the three questions discussed in Chapter 5: *What questions does the technique pose?*; *What is the ‘step-character’ of the technique?*; and *What is the nature of the emergent result throughout the technique?* To further evaluate the usefulness of these questions, future studies could look to alternative contexts, be they more collaborative (as discussed in 7.2.1), or involving different forms of material engagement[1]. Although it is expected that the appropriateness of each question will vary with different techniques (see 5.), trying to apply them more widely would help to refine and extend their usefulness.

As described in 2.6.6, I have made sure I feel competent in the practice of a technique before attempting to study its epistemic character. This prerequisite would be harder to maintain with an expanded survey. It seems necessary, therefore, that further studies would need to be performed alongside a competent practitioner. Having discovered throughout this research the wealth of information available on techniques (from online sources, to more traditional how-to books), however, I would suggest that a researcher need not embark on these studies of practice from an uninformed perspective. As I discuss in 2.6.9, the body of ‘interactional knowledge’ (Collins, 2004) associated with a practice can offer an extremely valuable understanding. To take an example from my own interest in woodwork, I suggest it is possible to learn all the principles of working “with the grain” (see 5.2.3) from just ten minutes’ reading (see, for example, Sundqvist 1990). I believe developing this kind of interactional expertise before trying to study techniques would be highly beneficial.

[1] A notable absence from the studies in this thesis is the consideration of digital techniques. Either in the techniques of digital designing (e.g. creating drawings and models within software), or digitally-controlled manufacturing techniques (e.g. laser cutters or 3D printers), I believe these alternative contexts would provide a diverse testing ground to explore how the idea of epistemic character may be extended.

From a personal perspective, I would be eager to conduct further studies of epistemic character in pursuit of a deeper insight into opposing philosophies of design (see 3.3 and De Landa 2001)[2]. As I discuss in my 'discursive contribution' (7.3), I believe the full significance of this thesis lies in the perspective it offers on the relationship between techniques and the qualities of their outcomes. For example, I consider the distribution of decisions throughout practice (as influenced by techniques) to have serious consequences for the quality of our artefacts and environments. According to this interest, I see great merit in studying the epistemic character of techniques that lead to favourable qualities, and comparing this to the epistemic character of those that do not. Although this kind of work would inevitably engage with the polemics of aesthetics, I also believe future studies could have less controversial purposes—for example in relation to design and craft pedagogy (see 7.2.4; Luscombe 2018).

7.2.3 Recording Methods

As described in 2.6.6 and 2.6.7, I have studied techniques that could be repeated very easily, to allow multiple attempts (e.g. hammering a pin). Documenting and reflecting on these studies by taking notes provided a satisfactory means of interrogating their epistemic character. If I needed to refine my thinking on a technique, I could easily repeat the operation and reconsider it according to my developing understanding of the research. Throughout the more idiosyncratic, temporary (non-repeatable) and less well-documented techniques that would likely be encountered in different contexts, however, the demands on recording methods would be increased. If, as suggested above, these contexts include collaboration between people (7.2.1), and a researcher not necessarily acquainted first-hand with the techniques (7.2.2), a richer record of events would have to be created throughout. I suggest the most appropriate, and least obtrusive, methods for this would be to make video and audio recordings. This would also have the added benefit of creating data that could be shared with others, for confirmation or reinterpretation.

7.2.4 The Pedagogic Potential of this Research

One of the contributions to knowledge claimed by this thesis is the way in which it communicates extra-disciplinary theoretical ideas in a way that is relevant for design practice (see 7.1, point no.7). This was motivated by an aspiration for the research to be read

[2] Having developed an ever-growing interest in the history and practice of woodwork throughout the course of this PhD, one of my specific ambitions is to consider how the different techniques within the craft correspond to particular philosophies of design.

by designers and craftspeople, and students of these fields. It follows, therefore, that I believe the content of this research could have important implications for the practice and teaching of design.

Reflecting on my experience as a tutor of three-dimensional design, I can offer a personal account of this potential. I have found one of the persistent challenges faced by students is to develop an efficient and thoughtful approach to prototyping. Owing perhaps to the long-standing theoretical division of designing and making (see Chapter 3), it can be difficult to explain the nature and value of an empirical, step-by-step approach to the making of designs. It is often clear at the end of a student project that those who employed means by which to test their ideas along the way are much more satisfied with the outcomes than those who optimistically leapt from the "idea" to the "finished thing".

I have found the discussion of epistemic character to be an effective way into this subject. By comparing, for example, the use of a spokeshave and coping saw to shape a piece of wood (see 6.6.1.), I try to provide an insight into how these techniques distribute decision making differently. The saw asks us to concentrate decision making in advance, and cut a line without reference to incremental feedback. The spokeshave enables us to advance incrementally, with continual reference to an emergent form. Even without any further elaboration on "epistemic character", or the "theory of extended mind", I find this observation has a useful effect—it demonstrates the idea that saws, spokeshaves and any other tool can be conceived as instruments of design, rather than just a means to make a pre-determined idea. My intention is to reframe all aspects of "making" as potential design techniques, and thus encourage a much more thorough engagement with prototyping.

More generally, this PhD has had a significant impact upon my teaching practice. Having become fascinated by the literature discussed throughout this thesis, I am more committed than ever to the idea of "thinking through making". And, having thought long and hard about what that phrase actually means, I feel much better placed to try and teach my subject. By publishing more sections of this thesis, whilst further refining their content, I hope to turn this insight into a value contribution for design and craft pedagogy.

7.3. A Discursive Contribution

In the final section of this thesis, I expand on my sixth contribution from above—the idea that some techniques distribute decisions throughout practice, and some concentrate decision making in advance. As discussed, I offer this in a more speculative spirit, in order to communicate what I believe to be the full significance of my prior contributions, without compromising the rigour of my previous claims. Whilst a thesis might typically close by pulling together points already made, this section is intended to suggest a potential future direction for further research. It concerns how I might try to articulate an issue that has been bubbling away beneath the surface of the research, as I saw links between disparate pieces of work and my own. The subject of this discussion is the aesthetics of diversity.

7.3.1. The Nature of Order

On reflection, I can trace the origin of my ideas on the distribution of decision making back to my first, serendipitous encounter with Christopher Alexander's four volume book *The Nature of Order* (2002). Browsing the shelves of the library one day, I picked out one of the volumes on a whim.

This would have been when I was between stages 2 and 3 of my T-shaped transformation (see 2.5.2). I was therefore in a state of open-mindedness, eagerly searching out as many new ideas as possible. This, and the fact that I had time enough to browse library shelves (an enviable luxury, from the perspective of someone trying to finish their PhD thesis), led me to sit with *The Nature of Order* for the rest of the afternoon.

In Alexander's work I found what I consider to be a practical application of a non-hylomorphic (see 3.3.1) approach to designing and making. Where the concepts of emergence and morphogenesis were, for most of the other authors I'd been reading, models by which to interpret the world, Alexander treats them as ways of acting. Here was someone following Andrew Pickering's suggestion to take the "performative idiom" (see 5.3.3) not just as a means of describing practice, but as an inspiration for how we should act in the world (2008; 2014). Pickering argues that our practices should 'emphasise a much more symmetric interplay of the human and the nonhuman […] in an open-ended, forward-looking, trial and error search process' (ibid., p.2). Within that first afternoon of reading, I began to see *The Nature of Order* as an account of how this idea might be pursued in design and making practice. In his straightforward descriptions of mocking up the steps of a porch, or using stakes and flags to generate floorplans on-site, Alexander demonstrated how his morphogenetic ideals informed his buildings.

Alexander makes no reference to Andrew Pickering's work, or indeed any of the authors with which I began to associate his writing. The majority of Alexander's arguments are substantiated through reference to his own architectural practice and intuition. He acts, as architecture critic Robert Campbell warm-heartedly observes, as if he ‘has never read a book’ (2012)[3].

Having made an early retreat from the field of design science (see 3.1.4), claiming it to be too little concerned with practice[4], Alexander has instead devoted his attention to the question of how to make good buildings. From *The Timeless Way of Building* (1979), to his most recent book, *Battle for the Life and Beauty of The Earth* (2012) Alexander has simultaneously sought to define “goodness” as a property of the environment, and discover how it may be created. The conflict suggested by the “battle” of Alexander’s recent work is a reference to the contrast at the heart of his theories; between modern approaches to design and construction, and the “timeless” way of building.

I interpret Alexander’s battle as set out along the same lines as Pickering’s comparison between a modern ontology of domination, and an alternative “ontology of becoming” (2009). Both Pickering and Alexander stress the failings of the modern paradigm, and the value of working *with* emergence, rather than trying to suppress it. They both promote back-and-forth experimentation in the world, instead of representational projects that seek to enframe and control it[5]. In one of many passages that typifies this approach, Alexander writes;

> [T]he 20th century mainstream view of building was goal-orientated and mechanistic, aimed mainly at end-results, not on the inner good of processes. Building was viewed as a necessary way to achieve a certain end-result. The design drawn by the architect—the master plan drawn by the planner—was the purpose, these were the goals of the art. The process of getting to the goal was thought to be of little importance in itself, except insofar as it attained (or failed to attain) the desired goal.
>
> The mechanistic view of architecture we have learned to accept in our era is crippled by this overly-simple, goal-orientated approach. In the mechanistic view of architecture we think mainly of *design* as the desired end-state of a building, and far

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[3] Robert Campbell made this remark at a ceremony to award Alexander the 2009 Vincent Scully Prize for architecture. Whilst at odds with prevailing thought in his discipline then, Alexander is not completely without allies. See 47 minutes into the video for the quote.

[4] In 1971 Alexander said ‘there is so little in what is called “design methods” that has anything useful to say about how to design buildings that I never even read the literature any more. […] I would say forget it, forget the whole thing. Period. Until those people who talk about design methods are actually engaged in the problem of creating buildings and actually trying to create buildings, I wouldn’t give a penny for their efforts.’ (1971)

[5] Pickering borrows the concept of ‘enframing’ from Martin Heidegger (1977), to describe a process that seeks to dominate nature by putting it at our disposal, whilst ‘at the same time, we enframe ourselves, becoming parts of a posthuman assemblage of production and consumption’ (2009, p.469).

> too little of the *way* or *process* of making a building as something inherently beautiful in itself. But, most important of all, the background underpinning of this goal-orientated view—a static world almost without process—just is not a truthful picture. As a conception of the world, it roundly fails to describe things as they are. It exerts a crippling effect on our view of architecture and planning because it fails to be true to ordinary, everyday fact. For in fact, everything is constantly changing, growing, evolving.' (2002, p.11-12, emphases in original)[6]

Throughout *The Nature of Order,* Alexander repeatedly challenges the dominant approach to design and construction in this way. With the ability to predict and determine the qualities of a building in advance of its construction being a central tenet of architectural practice[7], however, Alexander's work strikes a heretical tone[8]. Alexander himself remains unapologetic about the controversial aspects of his work, describing this presumed ability to make successful decisions according to the feedback of drawn lines or computer models as a 'polite fiction' (2002, p.245).

For all its heresy, however, a notable feature of Alexander's work is how old-fashioned the processes he promotes are. The timeless way of building was, at one time, the typical way of building. In David Turnbull (1993) and Lars Spuybroek's (2011) accounts of Gothic ontology, with their laboratory-like, empirical experimentation, we find that Alexander's brand of morphogenesis was ubiquitous. Indeed, for Alexander, the Gothic masterpiece Chartres represents a magnificent architectural achievement. This is a success he assigns to the emergent nature of its design. Given this, and the other historic examples he draws on, it is perhaps only from the perspective of a modern ontology of 'detachment and domination' (Pickering 2008, p.3) that Alexander's work appears at all controversial.

Despite Alexander's admiration for the built environment of previous eras, he still provides examples within the modern era that point towards what an alternative paradigm might offer. Alexander's examples include customized trucks or motorbikes that have been 'imbued with love and attention by their makers or their owners' (2002, p.146); the 'unfolded' character of Lower Manhattan Island (ibid., p.142-3); high-speed trains aerodynamically shaped in

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[6] On this point, Stewart Brand's book *How Buildings Learn: What Happens to Them After They're Built* (1994) provides a practical insight into the ever-changing nature of buildings.

[7] Anthropologist Wendy Gunn (2002), in her doctoral study of the influence of CAD software on architectural practice, describes that the ability to conceive the correct solution in advance of its being built is considered a key criterion of competence.

[8] See the 1982 debate with Peter Eisenman (Alexander and Eisenman 1983), for an example of the negative reception Alexander's work has received amongst other architects.

computer models and therefore ‘generated by a dynamic process in an evolutionary way’ (ibid., p.152); and the art of Matisse.

One of the most striking characteristics of Alexander’s work is the seriousness with which he treats his subject. As demonstrated by his early dismissal of an abstracted approach to design science, Alexander is not motivated to create theory for its own sake. *The Nature of Order* is the work of a reflective practitioner looking to make explicit his ongoing struggle to understand the world, and how it could and should be worked by humans. Any theoretical contributions seem to almost fall out of Alexander’s architecture. It is as if his architectural practice is itself a method of scientific investigation, continually trying to answer the question of how we can make beautiful places. Central to this effort is the way Alexander treats the quality of our environment as a vital concern. For Alexander, the quality of our surroundings is too important a subject to subscribe to the dispassionate post-modern idea that anything goes. Alexander does not believe that we should operate on the understanding that there are a range of equally valid opinions about what our built environment should look and feel like. This, he argues, has only ‘provided justification, validation, and therefore an intensification’ of developments that are ‘at odds with the organic harmony of towns and land’ (ibid., p.135).

Despite this commitment to the idea of an objective “goodness” to which our buildings should aspire, Alexander does not insist on stylistic homogenization. Unlike, for example, Ruskin’s admiration for Gothic architecture, he does not look for answers in the results of an “ideal” material culture. Although highly attuned to the physical facts of their success, what Alexander finds in his positive examples is not a style to emulate, but a process. In different times and places, Alexander acknowledges that there will be a variety of outcomes. But what he finds in successful cities, buildings and artefacts is an underlying sequence of design that was essentially step-by-step. Decisions were made along the way, with respect to the emergent result.

Perhaps inspired by the way his work on pattern languages has been adopted by software developers, Alexander argues that this same step-by-step character is essential to success in all creative endeavours. From the scale of making a single wall tile or painting, up to making an entire city, Alexander claims that step-by-step processes are always a pre-requisite of good results. The majority of Alexander’s examples, however, are taken from his experience of making buildings. In a description typical of his work, Alexander documents the process used to design the arrangement of panes in a window frame, when building a house. At this stage, the rooms of the house had already been built, and the size and position of the window determined (also via an on-site sequence of decision making).

‘In my experience,’ Alexander writes, ‘this is always torture. It seems easy, but is actually hellishly hard. We usually do it with surveyor’s tape, pinned or stapled to the window frames, so we can look at the effect of different patterns on the building, from inside and out. It takes days, sometimes even weeks.’ (2002, p.617). In this one example, we find both evidence of Alexander’s commitment to full-scale prototyping, throughout the building process, and the justification for such an approach. Following this method allows Alexander and his team to evaluate what the window is like from both the outside *and* the inside. This is a simple reason for not making the decision via representations, in advance of building. For Alexander, being able to stand inside and look out of the window is a crucial strategy for success.

Alexander attributes the difficulty of these decision to the fact that the preferred solution as generated from inside each room might result in an external appearance of disharmony between the different windows. If he was drawing the façade of the building, having not been inside the rooms, the harmony of the windows from outside might be much more easily realised. But this would almost certainly be to the detriment of the experience of being in the rooms. That this process can take days or weeks is a result of the significance Alexander attaches to the decision. It also allows for the fact that the light entering a room changes with the time of day, or in different weather conditions. And that, having left the prototype frames in place as the team move around the site, working on other parts of the building, new solutions might present themselves over time.

Some might argue that virtual reality models would enable the same experience of standing inside a building, via a computer-simulated representational approach. You could accelerate the motion of the computerised sun’s path through the sky, to test the design at different times of day. And using haptic gloves or a stapler-like peripheral, we could even model the technique of applying surveyor’s tape, to redesign the window in real-time. I would contend, however, that these ideas express an almost absurd commitment to prioritizing planning and representation over first-hand experimentation in the real world. Is it not simpler to organize the whole process, as Alexander demonstrates, so that decision making can be accommodated throughout the building process? On this point, I return to Andrew Pickering, who would characterize our imagined effort towards hyper-representation as a “detour” symptomatic of the modern paradigm’s techno-scientific tendencies (2008; see 5.3.4). Rather than adopting a performative, materially-engaged approach that makes use of the way things are, we instead go via vastly expensive detours in an effort to model, predict and control the world. It would, I suggest, be better to apply an idea from the theory of extended mind—when the world is its own best model, why bother to make a representation (Clark 1997, see p.29)?

7.3.2. Zooming in on The Nature of Practice

As documented throughout this thesis, my research has been inspired by a variety of scholars from a range of disciplines. Perhaps the most influential motivation however, has come from the idea that I have been developing a complementary, "zoomed-in" account of Alexander's step-by-step theory, at the scale of workshop practice. Throughout my research, I have been encouraged by the consequentiality Alexander attaches to his work. In contrast to the majority of design theory I have read, which rarely takes a strong stance on what might be preferred outcomes, Alexander is fully committed to his vision of better world, and the idea of step-by-step process as a means of achieving it. In times of doubt, I have been reassured of my topic's significance by reading pages at random from *The Nature of Order*. Even the shortest snippets of the book serve to remind me that 1) the quality of the human-made world is vitally important and, 2) our techniques of designing and making are directly responsible for this quality.

My adoption of Alexander's work has, however, been tempered by its relatively unscholarly approach. Where Pickering and the other thinkers I associate Alexander's work with set out their philosophical precedents and publish via peer-review, Alexander himself is somewhat of a lone wolf. And, whilst his earlier work is widely-cited across a range of disciplines, *The Nature of Order* seems to have generated little academic attention. It is in accordance with my commitment to scholarly rigour then (see 2.4), that I present this section as a "discursive contribution"—as a topic for discussion rather than what I would consider a substantive argument.

Caveats aside, I believe aligning my research to Alexander's work on step-by-step processes is the key to unlocking its full significance. If we accept the central theme of Alexander's work—that the distribution of decisions is fundamental to the quality of creative processes—I believe the concept of 'epistemic character' would be of great value. In addition, I believe my research can help to refine aspects of Alexander's theories. My discussion of how techniques distribute decision making, for example, is closely related to Alexander's contrast of the modern and traditional architectural paradigms. Where Alexander presents a polarized caricature of processes being *either* step-by-step (good) *or* planned in advance (bad) however, I believe my appropriation of Tim Ingold's models of wayfaring and transport offers a richer evaluative scheme (see 6.3). Through further studies of epistemic character, I would be eager to pursue these links between my research, Alexander's work and the wider theoretical foundation I have developed throughout this research. It is in this spirit that I have developed the following, final topic of this thesis.

7.3.3. David Pye and Diversity

I end this chapter, and the thesis, with a discussion of one more theme from David Pye's work. I hope to show how the concept of epistemic character, and Alexander's work, can help us to re-evaluate Pye's discussion of "diversity"—an aesthetic quality of the human-made world that he most admired.

Pye presents a series of photographs to help define his concept of diversity. The accompanying descriptions show Pye, for all his scientific allusions, to be deeply sensitive to artistic concerns. A thirteenth century stone stature 'is a masterly demonstration of the principle of diversity [wherein] small elements barely at the threshold of recognition are capable of intensifying the character of the larger forms which underlie them' (1968, p.74). A well-worn tobacco box 'is beautifully diversified in a way typical of much silver, through the shading and reflections created by its pebble-like shape, through the quality of the engraved line, and through the quality of the soft faint mesh of dents and scratches in the metal' (ibid., p.69). And a contemporary building is 'of an austere design yet it has an attractive dignity and calm about it. The stonework of the pillars is of moderately free workmanship, and this, with the character of the stone surfaces and their fossils, has lent it a diversity which prevents it from being forbidding' (ibid., p.78).

A key element to Pye's principle of diversity is formal interest at different scales. The diversity lent to the building by the texture of the stonework, for example, becomes apparent only as we draw near. Although he also describes a kind of 'medium-scale diversity' (cobbled paving, or brickwork are two examples) (ibid., p.63), it is the finer textures of surfaces with which Pye is most concerned. And it is for this reason that workmanship is such a critical subject;

> '[W]orkmanship provides formal elements, and important ones, which are outside the control of design: of what, for practical purposes, can be conveyed by words or drawing. These are, of course, short-range elements. Most of them are still at, or little above, the threshold of recognition at those close ranges at which we normally see the components of our environment when we are using them: in a room, in a vehicle, in a street, on a bench or table, in our hand. For most of your life the parts of your environment which you are looking at are likely to be at close ranges of that sort; not on a hilltop, or in the distance, or as seen in the photographs in architectural magazines. It is for this reason that the art of workmanship is so evidently important. It takes over where design stops: and *design begins to fail to control the appearance*

of the environment at just those ranges at which the environment impinges on us.' (ibid., p.62, emphasis in original)

Pye found it very rare for diversity at this scale to be created through the workmanship of certainty; contemporary determining systems were unable to diversify surfaces to the degree afforded by the 'slight improvisations, divagations and irregularities' (ibid., p.63) of more risky techniques. Much more easily achieved were the 'clinical' surfaces of hospital and laboratory apparatus, which, whilst practical in the right context, Pye thought would 'come to seem infuriatingly vacuous' (ibid., p.70) if proliferated more generally.

Such proliferation was a risk that Pye took seriously. He bemoaned the lack of appreciation for diversity across the industrial design and architectural professions. 'One almost believes,' he writes, 'that some industrial designers only know of two surface qualities, shiny and "textured"; and that to them texture means something which has to be distinguishable in all its parts three feet away!' (ibid., p.130). The sentiment underlying this statement is perhaps the one that motivated Pye to write *The Nature and Art of Workmanship* in the first place. 'If industrial designers and architects understood the theory and aesthetics of workmanship better, and realised the importance of it', he thought that 'they would surely make better use of the opportunities offered by the techniques which are now available to them' (ibid., p.130). The way Pye contrasts the "vacuous" appearance of undifferentiated artefacts with his celebrations of diversity—'[t]he beam of the engine and its ancillary parts are extraordinarily diversified and their appearance is delightful' (ibid., p.71)—can thus be seen as part of an educational project.

7.3.4. Nearly Romantic

In his assessment of Pye's writing, Glenn Adamson finds Pye's attitude to the topic of diversity to be 'nearly romantic' (2007, p.75). For Adamson, it represents a slip in Pye's otherwise rigorous logic, as he adopts the tone of 'a heartbroken lover rather than the coolly rational analyst we have come to expect' (ibid.). Elsewhere, Pye is able to maintain the equal-standing of risky and certain workmanship, continually at pains not to promote the work of the hand over the machine. In his appreciation of diversity however, Pye must admit that it is almost exclusively a product of the workmanship of risk[9]. In the techniques associated with the underwood industry (e.g. traditional methods of making wooden hurdles or spoons) or blacksmithing, Pye finds a special kind of "free workmanship". 'There is', Pye

[9] On the subject of creating small-scale diversity Pye writes ''It is rarely possible to do this by the workmanship of certainty, but always possible by the workmanship of risk, and particularly easy by free workmanship' (1968, p.63)

writes, ‘no substitute for the aesthetic quality of this workmanship and the world will be poorer without it, particularly the countryside’ (ibid., p.36). In reaction to this point, Adamson goes so far as to suggest (in a knowingly ‘mischievous’ fashion) that Pye’s analysis ‘veers surprisingly close to the ideas of Ruskin, his *bête noire*’ (2007, p.75).

Pye’s rebut would no doubt be that it is not the risky or skilled nature of the country crafts’ processes he is lamenting, but the qualities of their results. He is certainly not suggesting that free workmanship might offer ‘a cure for the miseries of industrialisation’ (1968, p.118), or advocating a retreat to an idealised bucolic state. Pye’s solution to the incapability of machines to produce diversity is not to stop making and using them, but to make newer, better ones. At the time of his writing, it was practically impossible to specify subtle diversity through drawings, or use machines to create it[10]. But Pye thought this was no excuse to give up on the idea—‘[a]rt is not so easy that we can afford to ignore any and every formal quality which will not go on to a drawing board’ (ibid., p.130)[11]. And he believes the matter to be as much a question of will as technical possibility—‘if people came to love diversity, they would find ways of producing it’ (ibid.).

Although it is more of a tentative prediction than an insightful prophecy, Pye was hopeful that CNC machines might one day allow for the creation of ‘diversity in shapes and surfaces’ (ibid., p.129). With the increasingly sophisticated computer controlled machines now available, perhaps we are at a point wherein the diverse qualities once achieved by dexterous hands have been made possible by more certain means. In those techniques that employ CNC routers, laser cutters, waterjet cutters, and 3D printers, we might have a suitably advanced form of the workmanship of certainty. And the software packages used to drive this equipment provide a means by which to specify surface texture with new found precision. Contemporary practitioners and theorists are demonstrating the possibilities offered by these new tools and techniques (see, for example, Marshall 2008; Jorgensen and Matthias 2014).

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[10] ‘This impoverishment’, Pye writes, ‘is the price we pay at present for cheap quantity-production in which only this very simplified level of communication and execution is practicable, and in which as a rule the slight free modifications of shape and surface quality which mark the workmanship of risk are quite unattainable and indeed unthinkable, except in cases where the material is flexible or translucent [such as the rippled inside of a glass jar, an example of which Pye provides a photograph]’ (1968, p.57)

[11] As an aside, I note that in quotes like this we find a tone similar to Alexander’s. In addition to the specific relevancy of his work, I am also drawn to Pye’s work for its deep sense of responsibility for the quality or our material world.

‘In principle’, Pye wrote, ‘nothing whatever is beyond the reach of design’ (1968, p.56). As it becomes possible to specify and produce any formal quality with precision, new techniques are turning this principle into a practical reality. Where diversity was previously a consequence of risky or free workmanship, it may now be formalised in pre-existing specifications, and then created with near 1:1 accuracy. In celebration of this opportunity, and inspired by Ruskin’s Gothic aesthetic of ‘[c]hangefulness, savageness and imperfection’ (2011, p.58), Lars Spuybroek argues that we must develop ways of generating these qualities (which I take to be synonymous with Pye’s “diversity”[12]) throughout processes of design. We must, Spuybroek claims, ‘bring craft to design’ (ibid., p.57). In a statement that mirrors Pye’s aspirations for simultaneous certainty and diversity, Spuybroek believes that our changeful, savage and imperfect creations should evolve during the design stage, and that their ‘final execution must be perfect - and done by slaves of steel’ (ibid., p.58). In this model, the creation of diversity, once a result of the free workmanship associated with hand tool use, has been shifted from processes of making, to instead be specified in advance of production.

It is here that I return to the ideas of epistemic character, distributed decision making, and the work of Christopher Alexander. I have argued that there is a more fundamental distinction than that of risk and certainty: between *processes through which things emerge step-by-step*, and *processes through which things are planned in advance of their execution*. And I now suggest that the diversity in the environment that both Pye and Spuybroek value might be understood not as a result of the *risk* of a process, but as a consequence of processes that allow form to emerge as a result of frequent improvisations and adaptations, made in response to feedback along the way.

According to Pye, ‘design begins to fail to control the appearance of the environment at just those ranges at which the environment impinges on us’ (1968, p.62). I would add that design also fails to control the appearance of the environment at much larger scales. The arrangement of country fields, or an old city, as seen from an aeroplane window could be said to have a diverse quality. Like the quickly hewn spoon, this is not a quality controlled by virtue of planning, it is a consequence of proximate decisions being made over a period of time. Perhaps, then, it follows that diversity occurs not *despite* a failure of design, but *because* of it.

[12] Pye himself makes this link, when observing that Ruskin ‘described and understood the quality in things which I have termed diversity’ (1968, p.126)

This is to follow Alexander's lead and argue for the importance of step-by-step processes. On this understanding, diversity is not associated with the risk of a technique, but its epistemic character. And to think it possible to transfer the creation of diversity into "design", without also transferring the epistemic character of formerly successful techniques, and their processes of distributed decision making, would appear too simplistic an ambition.

Under his ideal of bringing craft to design, Spuybroek suggests that computer code should become the material with which we engage. He discusses at length the methods of coding that he feels could replicate the favourable qualities of Gothic architecture. I suggest that this effort could be complimented by a thorough investigation of the epistemic character of Gothic stone masonry. Without a means for understanding the process of decision making performed by Gothic masons, how can we know what to code? If we don't yet have a means for the describing the relatively simple epistemic character of carving a spoon and how it distributes decision making, how can we be expected to develop successful algorithmic approaches to designing complex things like buildings? I believe that the concept of epistemic character, and the associated ontology of emergent production, might have real value in these areas.

I end with a different kind of masonry. Inspired by Pye's paean for countryside aesthetics, I present a quote from a builder of dry stone walls. For me, it perfectly captures the technique's epistemic character, the extended nature of mind and the kind of step-by-step processes that lead to a diverse, and beautiful, world. In response to philosopher Andrew Harrison's questioning, as to how one goes about making a wall, '[t]he answer was simple enough, there are two things to remember, never, after picking the stone up put it down except onto the wall, and that the stone decides the right way for it to go' (1978, p.76).

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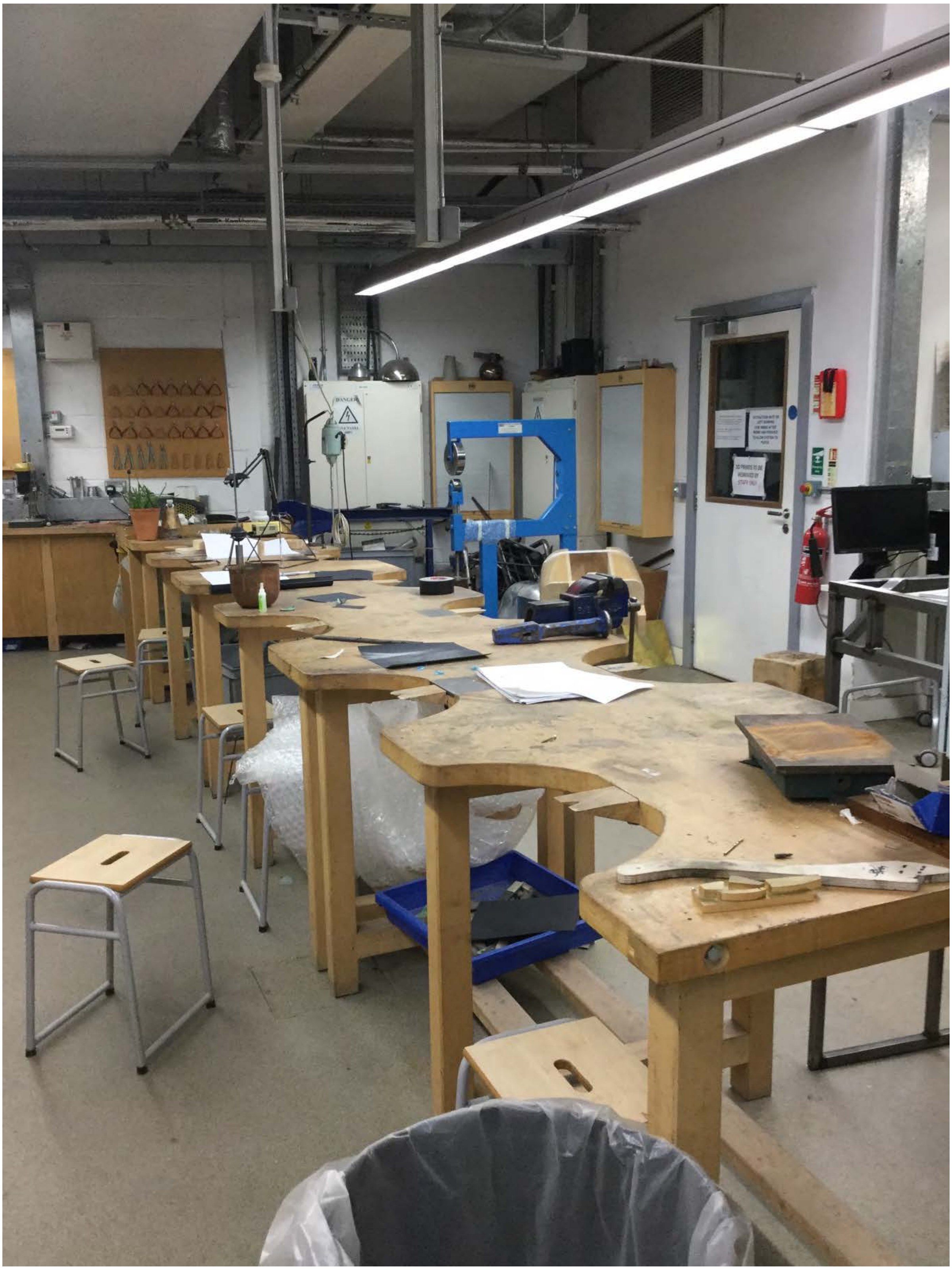
Appendix

1. Photographs of the workshop environments that were the setting for this research.
2. Scans of notebook pages.
3. A selection of photographs used as a basis for the line drawings.

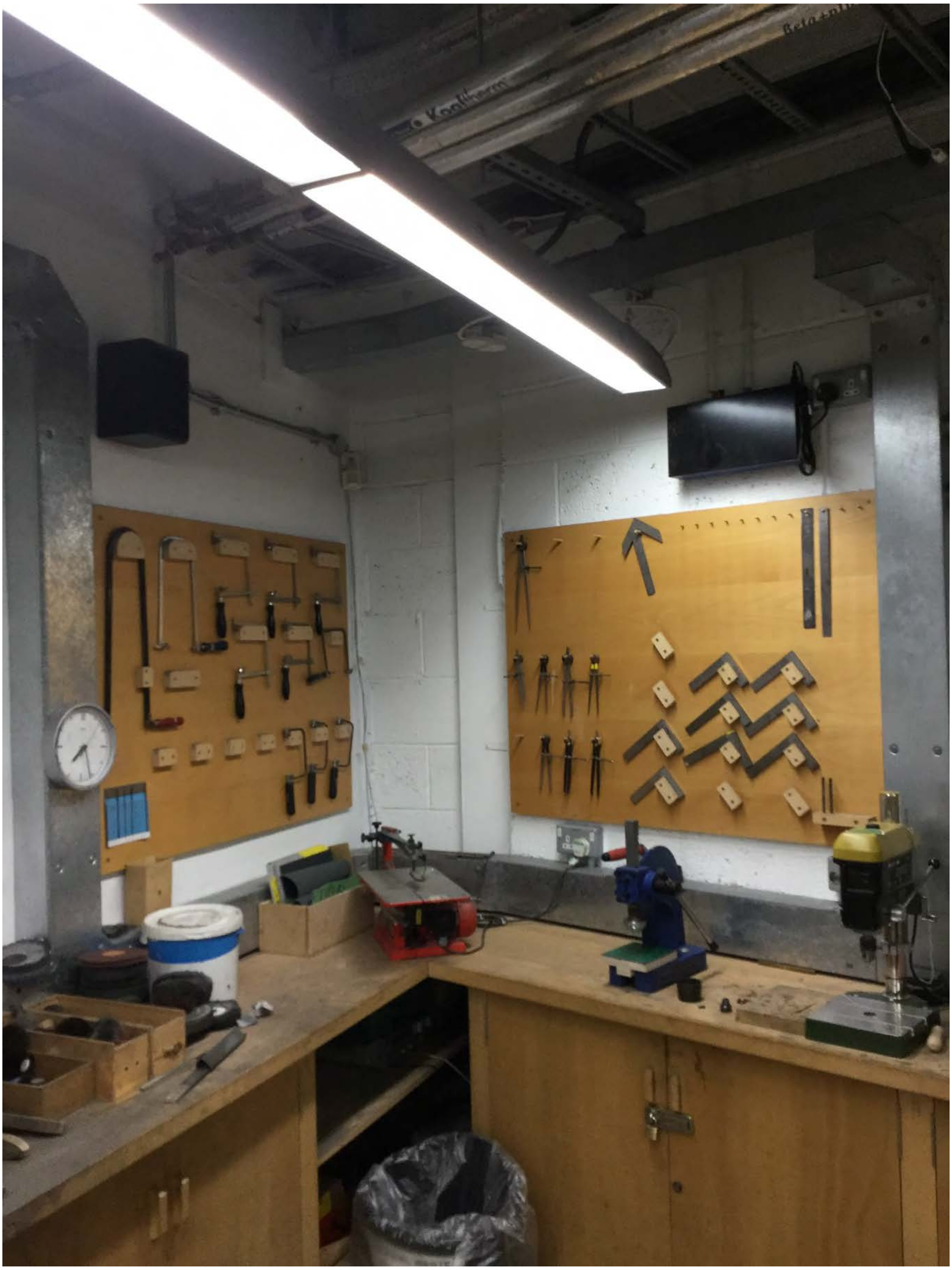
1. Photographs of the workshop environments that were the setting for this research


FIRST AID

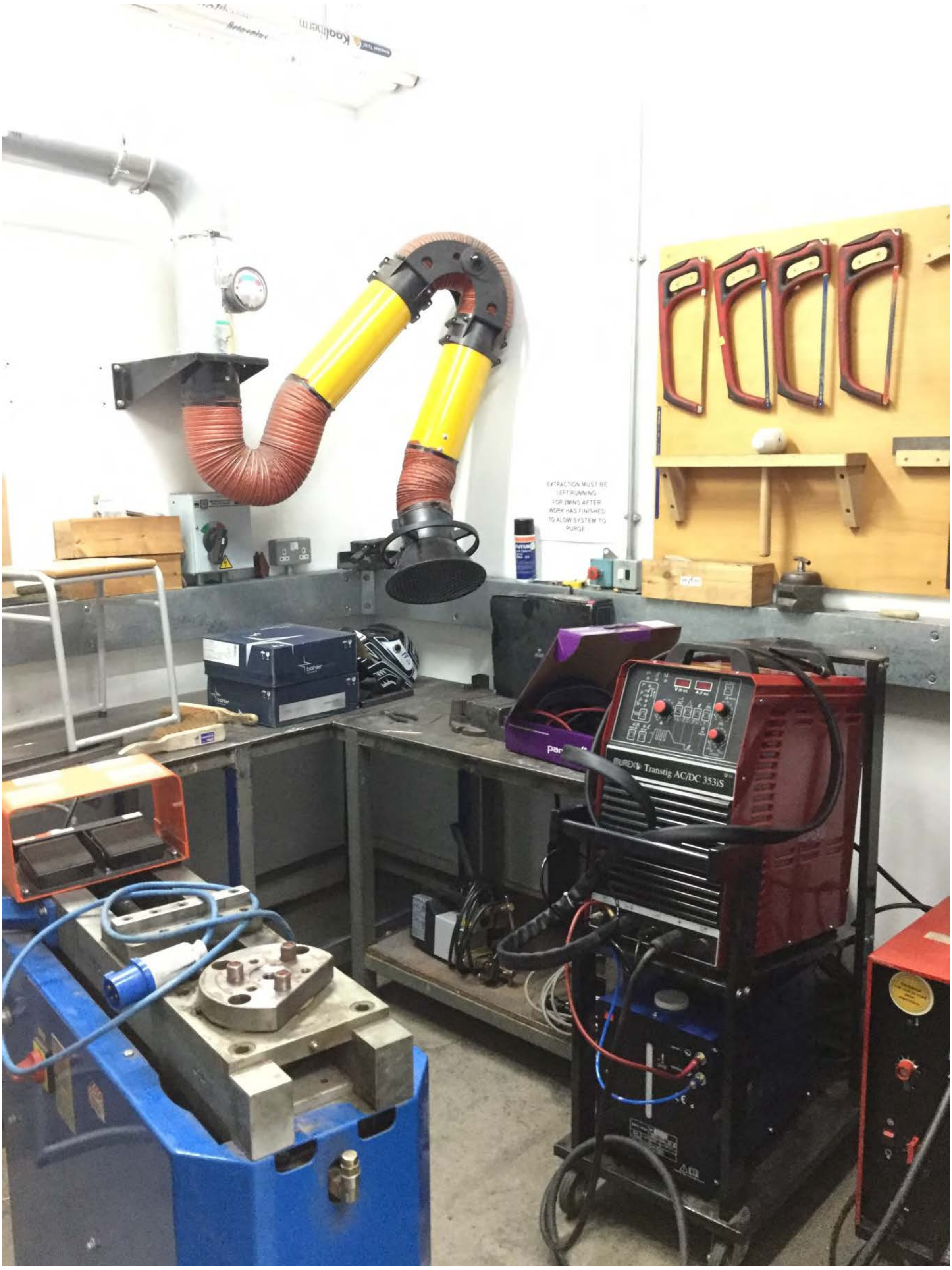

FIRE
EXIT
STOP
CHAMOIS



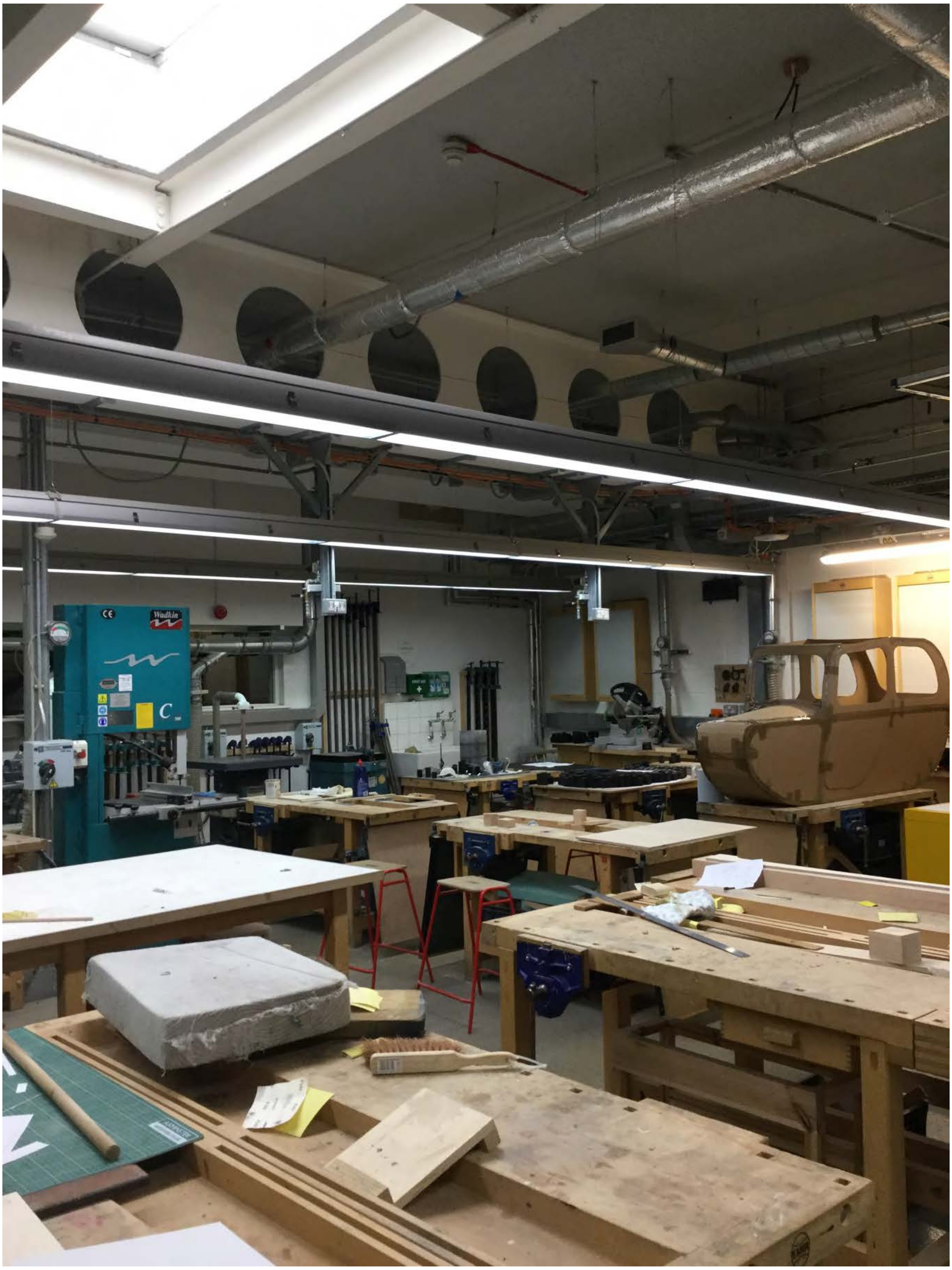

Sharpsafe
DANGER
tgs

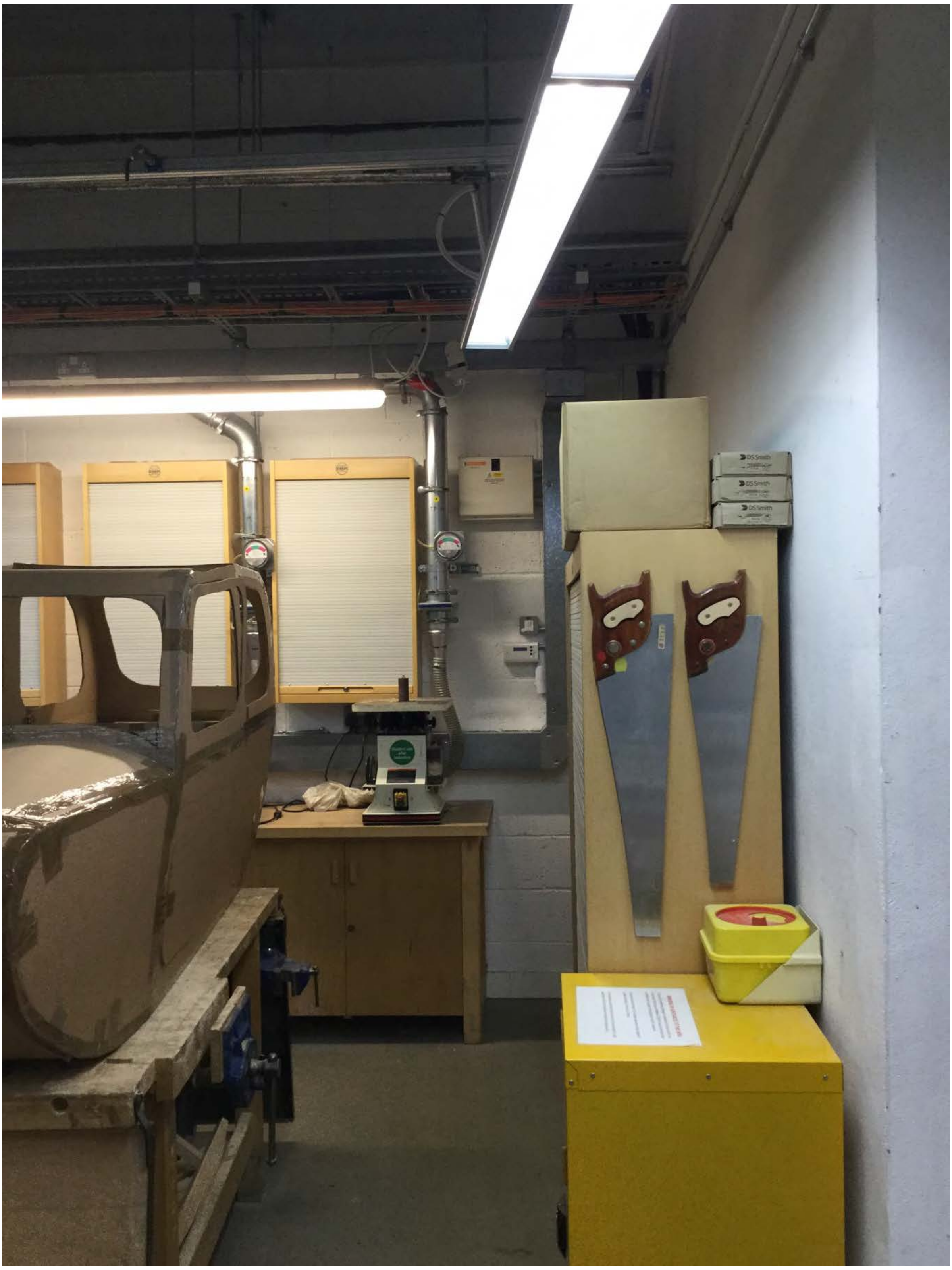



Welding
bottles must
only be
operated by
a member of
staff.


EXTRACTION MUST BE
LEFT RUNNING
FOR 2MINS AFTER
WORK HAS FINISHED
TO ALOW SYSTEM TO
PURGE
Transtig AC/DC 353iS


EPILOG
www.epiloglaser.com


Wadkin




SANDER


Variturn
DALTONS
Variturn
WARNING


FIRE EXIT
Culture
T500
Wadkin


MEDDINGS
DALTONS
Brookman


FIRST AID


ELCON
0
1


EX
F45


FIRE
EXIT


3D PRINTS TO BE
REMOVED BY
STAFF ONLY


VACUUM FORMER 1820

PLEASE LEAVE THIS
MACHINE HOW YOU
FOUND IT !
B
C
Student
2500
Colchester
Master 3250
D


INDICATORS
GAUGE BLOCKS
Bridgeport by
ADCOCK-SHIPLEY


SHOP RATE:
$45 per hour
$55 if you looked at it.
$65 if you touched it.
$75 if you watch!
$100 per hour if you


TL 1
Staff use Only
HAAS
E


MICROMETERS
EDUCATIONAL WALLCHART 2
Workshop Safety sticker information
IS900
Staff use Only

Carving stump and axe in the researcher's garden

2. Scans of notebook pages

The series of notebooks used throughout the research. The following selection of pages are presented in chronological order.

-on's stuff about the relational nature of Gothic is
lar to Ingold's stuff about the entanglement of things
world.

→ PRIORITISE THE CREATIVITY OF IMPROVISATION OVER THE CREATIVITY OF 'INNOVATION'
ROVISATION / DOING THINGS ON PURPOSE) / AGAINST ABDUCTION OF ARTEFACT
ALITY / 'THINGS' / GOTHIC → UN-DEDUCTABLE
ENT (MYSTERY / SKILL → VARIATION IS SHIT WHEN IT IS THE RESULT OF RESISTANCE - WHEN IT'S IN PYE'S DESIGN STAGE, NOT WORKMANSHIP
ALSO, 'IMITATION' MATERIALS FREE WHICH REPRESENT THE RESISTANCES OF OTHERS ARE 'CODE'. IT HAS TO BE THE RESULT OF CREATIVE IMPROVISATION
(GOTHIC / CODE — GENRES DO NOT
HOW CAN YOU HAVE VARIATION BUT SHIT THROUGH MATERIALS? HOW CAN YOU RELY ON THEIR PROPERTIES FOR THE VARIATION?
2000 / 60 — w/ JUST SET PARAMETERS
e world. But, then the environment happens & RELATIONSHIP OF DESIGNER / MAKER
DS TO QUESTION OF INTENT,
TION OF 'QUALITY'.
ORE THIS IDEA, IN CONTEXT OF LOW VOLUME PRODUCTION.
MING PROJECTS EXPLORE
TO 'HYLOMORPHIC' MODEL
MAYBE DO SOMETHING WHICH EXPLORES THE IDEA OF A PRIORITISED 'QUALITY' EG. FLATNESS
SHOW THE WEAKNESS OF THE CONCEPTION + THEN MOVE ON TO PROPOSE ALTERNATIVE
LOW VOLUME
A BIT LIKE THAT GUY'S 'SOLAR SINTER' MACHINE, RELYING ON THE SUN. THERE'S A FRAILTY TO THE PROCESS. IT RELIES UPON THE ENVIRONMENT. BUT MAYBE NO MORE SO THAN MY SCISSORS, IT JUST MAKES THIS QUITE EXPLICIT.
REDUNDANCY
↓
COULD THIS BE DONE DIGITALLY SOMEHOW? PROB. NOT.
RATHER THAN A PRIORITISED CONSTRAINT eg. TIME / MONEY.
PYE'S BOWLS INSTANTIATE HIS IDEAS ABOUT VARIANCE + SKILL - WHAT CAN I DO? COULD I MAKE A BOWL OF HIS?
on's 'Aphid. of Mat. Cul.':

-visation displays a kind of creativity distributed throughout
n itself.'

influenced by material engagement
quires a sensitivity to preferable attributes which can be
throughout production. → so can anything of value ever come off a Makerbot? when there's no resistance to respond to? Since all 'quality' craftwork might be characterised by an engagement with resistance. Maybe the resistance is in the software, or Shapeways's model checker.
THIS HAPPEN? the
ellow book - is judged by BUT NOT NECESSARILY CREATED BY
workmanship i.e. the intended design to user
-ance is important too
-based observations of quality

Ingold tries to remove the divide between 'cognition' + 'action' when considering skilled practice.

Ingold + Hallam's introductory essay to 'Creativity and Cultural Improvisation' is great. It pulls apart 'innovation', or the judgment of creativity by reading the novelty of its results backwards + promotes the case of improvisation (in an ever changing world) as being equally creative. It says that innovation is a notion of the modern world.

Along with Ingold, I don't believe that 'thinking' or cognition can be separated out from perception + action in skilled practice. So why interview / observe craftspeople? Or anyone doing anything, a good chef or bricklayer?

Look at Pye's Yellow book chapter on 'Quality in Workmanship'. He says that the workmanship of certainty is currently incapable of 'freedom'. I wonder whether he would consider CNC machines as free? I doubt it. I think freedom has less to do with variation of designs than improvisation of action, as guided by prioritised attributes. → OVER PAGE.

The chapter is, by the way, all about the realisation of intent, workmanship. I'm trying to update Pye's work here, with reference to Preston, Ingold, Spuybroek etc. + consider the quality of workmanship in the context of contemporary low volume production.

Could I do a 'photo-essay' of things which have 'quality' values related to my literature review. Like a really 'specific', entirely positive contextual review.

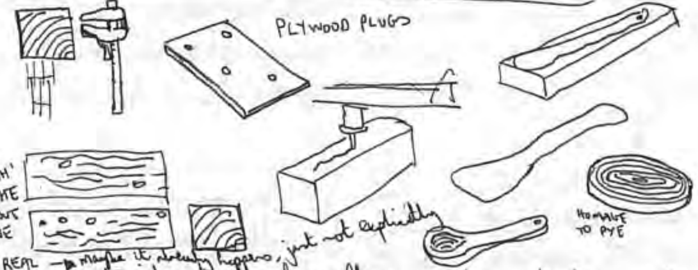
Pye makes the complete distinction between designs + workmanship, but I could say that my designs are designs for workmanship.

LLOW BOOK - Pye discusses a jam jar where diversity
lt of material 'will', rather than ~~the~~ designed variety.

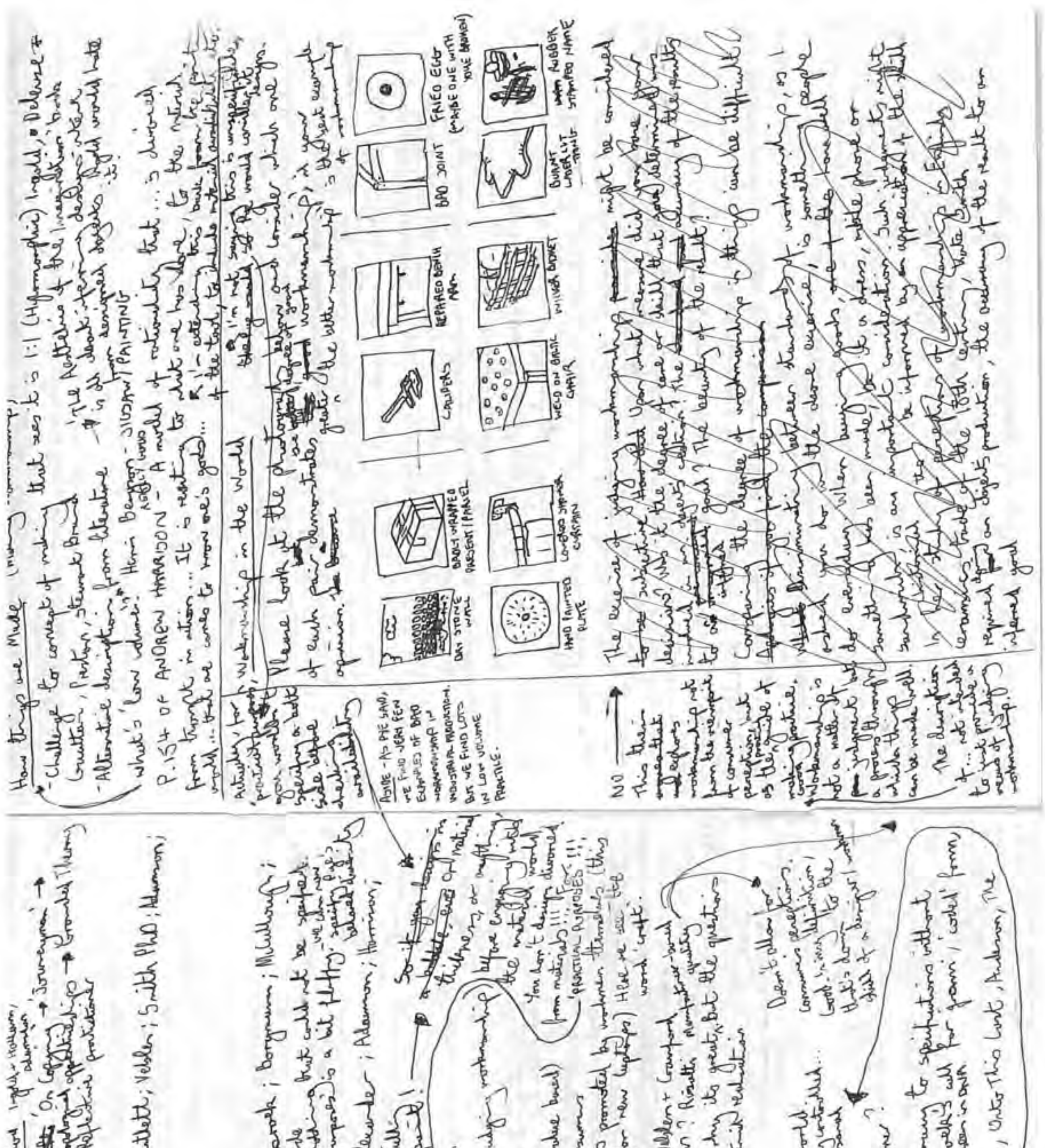
Stewart Brand - 'How Buildings Learn' - IN LIBRARY - Observes how the
eit of modernist architecture is based on permanence.

in to utilising digital is to introduce the growth + redundancy
ic ontology. I see the variance which is championed
r Ruskin to be one form of ~~sub~~ improvisational
engagement. Any code ~~g~~ that pre-generates form
arameters, like genes, still does not take into account
tial resistances during the making process. Los
against calls to combine hand + machine in
d of backwards compromise. For him, we should
digital production, recognise the variance it
d develop an ontology of design which 'grows' form.
d design parameters. He argues that this is,
, what happened in the production of Gothic
e. But he takes the 'risk' for variance out
nds of ~~a~~ the workman + places it in the lines
Before, the variety came through the improvisation of
man as he engaged with material resistance. Los
e improvisation 'upstream' in the process, to the
design. Using Pye's description, the variance is
design phase, not ~~-~~ improvised through workmanship.
t appear to be untrue if the code grows from
material, + it emerges almost biologically, so that
s form is not fully specified at its foot. Perhaps ~~at~~ after
centimeter the code is re-run to determine the

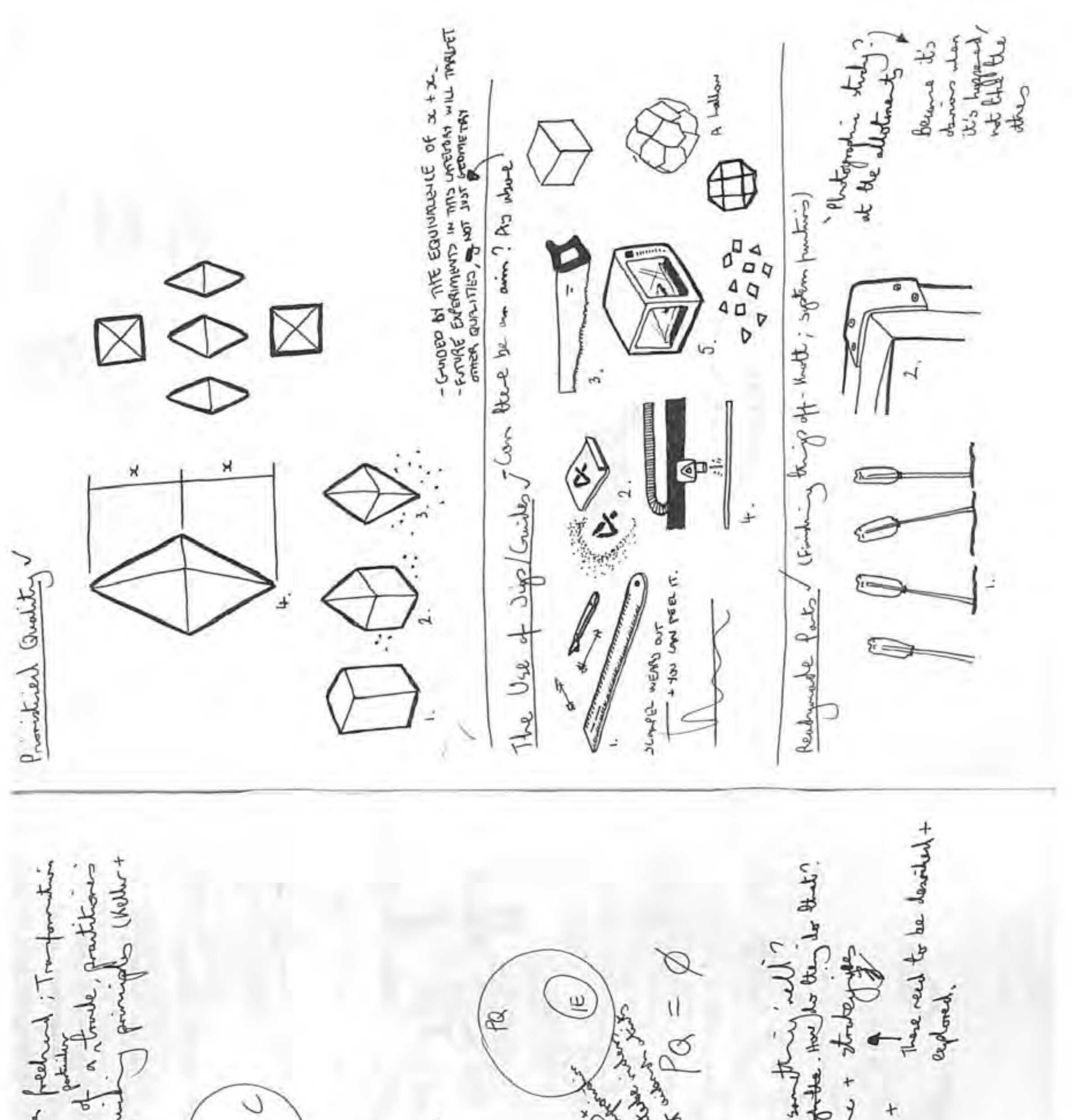
next section. Each ~~seg~~ length is both informed by the existing form
and, within the parameters, free to 'build on' this in its 'own'
way. But this sense of 'improvisation' seems like little more
than an illusion. One can imagine running such a program
inside computer simulation, clicking and re-clicking a 'Build'
button, ~~and~~ seeing variations of a column being realised
again and again. Because of the ~~proud~~ prioritisation of
design over workmanship, because in this model workmanship ~~is~~ is
considered an absolute certainty, because of the triumph of
architecture over building, it all seems deeply unimpressive.
Something about temporality, maybe ingold + hallam mention this?
Not sure that this portray's Los ideas correctly, but he gives few examples
of how this would actually work in practice.



HOW CAN YOU DO THE 'GROWTH' IDEA WITHOUT THE CODE SHIT + WITHOUT THE SKILLED STONE MASONS? IN THE REAL WORLD, WITH MATERIALS. → Maybe it already happens, just not explicitly → Materials already have their own 'parameters' encoded,
their resistances + affordances. So if you reconsider what a wooden
spoon should look like, and ask, 'what if it is wrong to cut it
along any line but the grain?', this might be interesting. Our
understanding of how it is acceptable to make things from wood
is only ~~a~~ cultural. We think it's fine to shape it to forms +
have the grain running off the edge. Rather than setting arbitrary parameters
on coded growth through or enforcing ones which are strictly
functional, how about setting them by the variance of
materials. Most CNC stuff currently insists on inert sheets of
compliant material. It's lifeless.



How things are Made
Challenge to concept of making that sees it is 1:1 (Hylomorphic) Ingold, Deleuze
Alternative description from literature
What's 'low volume'?
P.154 OF ANDREW HARRISON
Workmanship in the World
Please look at the photographs below and consider which one of each pair demonstrates good workmanship, in your opinion.
ASIDE - AS PYE SAID, WE FIND VERY FEW EXAMPLES OF BAD WORKMANSHIP IN INDUSTRIAL PRODUCTION. BUT WE FIND LOTS IN LOW VOLUME PRACTICE.
DRY STONE WALL
BADLY WRAPPED PRESENT / PARCEL
CALIPERS
REPAIRED BENCH ARM
BAD JOINT
FRIED EGG (MAYBE ONE WITH YOKE BROKEN)
HAND PAINTED PLATE
WELD ON BASIC CHAIR
WICKER BASKET
RUBBER STAMPED NAME
Potentially BIG point!
You don't design divorced from materials!!!
'PRACTICAL PURPOSES' !!!
Workmanship in the World
Problems of expressing these ideas
Don't allow for consumer perceptions.
LOW VOLUME


...ing Principles Think Hot; work freehand; Transformation
...ups influenced by the conventions of a particular trade, practitioners
can be informed by a set of guiding principles (Keller +
...) e.g. when
... the senior
..., the principles of
-free writing and 'demountability'
important.
A
B
C
A ∪ B
A ∩ B
A ∩ B ∩ C
PQ
IE
PQ
...o you evaluate the contribution?
with reference to existing studies of making e.g. writing + cultural information + youtube videos of artists
IE ∩ PQ
PQ = ∅
How does someone make something 'well'?
They negotiate resistances through the... How do they do that?
Framework of resistance + strategies
These need to be described + explored.
The best way to understand, explain + discover the strategies is by practical experiments
Prioritised Quality ✓
x
x
4.
1.
2.
3.
- GUIDED BY THE EQUIVALENCE OF x + x.
- FUTURE EXPERIMENTS IN THIS CATEGORY WILL TARGET OTHER QUALITIES, NOT JUST GEOMETRY
The Use of Jigs/Guides ✓ - Can there be an aim? As above
1.
SCALPEL WEARS OUT + YOU CAN FEEL IT.
2.
3.
4.
5.
A hollow
Readymade Parts ✓ (Finding things off-Knott; system punters)
'Photographic study? at the allotments'
Because it's obvious when it's happened, not like the others
1.
2.

e

the resistance of
...own on P.5 of my diamond making notes, material resistance is not always negative – none of the resistances ...ther positive or negative, they are 'facts that stand in ...way of will'. It is the preferences of will that colour ... with a positive or negative value.

...ike to show how the big ideas of duration, rhythm, ...tion, feedback etc. ~~which~~ are evidenced at the level of ...idual movements + the task as a whole. This is ...thing Ingold suggests implicitly, by using examples of ...y, basket weaving to describe human action, but ...'t go all the way in ~~showing how this is applied~~ ...y out how this works at different levels.

... OF BANDSAW CUTS

RISK OF FILING

(POTENTIAL FOR FUCKING UP IN ONE STROKE)

– So, good workmanship knows when to change tool / process. – LINK OF THE KNOWLEDGE + SKILL/DEXTERITY ?

...so good dexterity risks? Pye considers ...ety/diversity of results. Maybe it's ...aptability

– The conditions of the task are subject to unpredictability – the broadly held understanding of 'risk'

...od thing in Bernstein is that ~~overall~~ unpredictable ...tions are both internal (muscle elasticity) + external ...ironmental). So I have resistances of dexterity + maybe change to skill? ...ledge (internal ones) + external ones such as ...ial availability

...ight have to acknowledge that Pye was right, that good ...manship is the accuracy to intent, but that intent can shift in ...se to an emergent task. It's guided by 'principles' as much ...pecification, and these principles can be achieved by ...ying strategies

Repetition – Innovation; when do you break the rhythm? – when something's done – how do you know it's 'done' – material feedback, which might be as subtle as a change in sound of ...

Rhythm – look up Boas in Ingold's ... for RHYTHM.

It is rhythmic. Knowing when to change the rhythm is important.

Making things involves repetitive actions. Take the A frame shown above... [Cycles of tool / machine use]. This account deals only with annealed brass. the processes as discrete units of production, ignoring the steps between machines, picking up and putting down of tools and components. [Rhythm]

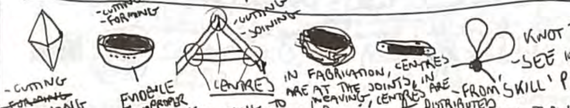
~~[Rhythm as]~~ [Repetition without repetition] [Learning a skill] Under uncertain conditions, we learn the process of solving a motor problem, not the solution. So a blacksmith's hammer can follow a different path but give the same solution. The essence of dexterity is not in repeating a learned movement, but ~~but drawing on a library of past solutions, to apply one in the present~~ [Sensitivity to conditions] It is this sensitivity to the emergent task that is important when deciding when to change the rhythm of production. ~~is broken~~. You've got to be aware of the risks at each stage.

* Challenge to 'uncreative' view of repetition, every cycle is creative, the solution ...

↑ Maybe split this into 'Skill' > 'Repetition + cope.' > 'Change the rhythm' > Risk/reward knowledge

(IN BOOKMARKS)

IN The Intro to 'Biosocial Becomings', Ingold uses his critique of hylomorphism to challenge neo-Darwinism – 'The scale of rethinking we are calling for here can scarcely be overestimated' (p. 9) – USE this to temper my use of his critique – I'm not using it anywhere near as radically + therefore need to be careful. But I suppose it's relatively radical for 'design'.



('LEARNING TO SEE VALUE' GOWLAND)

IN FABRICATION, CENTRES ARE AT THE JOINTS, IN WEAVING, CENTRES ARE DISTRIBUTED – Learning to see,

e.g. Coleman's increased appreciation for forests. – P.137

KNOT TYING, AT MANCHESTER I'VE TRIED TO LEARN KNOTS – SEE INGOLD – FROM 'SKILL' P.25 ABOUT SHOELACES

WEAVING JIG

TECHNIQUE
– FORMING
– CUTTING
~~MOULDING~~
– JOINING – JOINTS ARE 'CENTRES'
– FINISHING
– TIME/PERCEPTION 'REPETITION'

'FABRICATION', FLAT + SQUARE

From Sigaut's 'Technology' in Ingold's Companion Encyclopedia of Anthropology (AVAILABLE AS UNI LIBRARY EBOOK) – P.435 Sigaut defines techniques as 'alternative ways of carrying out a given operation.' Sigaut discusses technology as

- In 'The Affordances of Things', Carl Knappett describes a post-Gibsonian perspective of material engagement. This is a really useful + good explanation of Gibson's affordances.

- Knappett uses the $\boxed{\text{JIGSAW}}$ example (p. 48) to describe the difference between 'pragmatic action' (fitting a piece where it should go + 'epistemic action', which is an evaluation before + after ~~execution~~ execution, eg. grouping all the sky bits together. - These categories came from... TETRIS - FLIPPING A PIECE TO SEE WHERE IT SHOULD GO

LOOK UP Kirsh + Maglio - 1994 - 'On distinguishing epistemic action from pragmatic action' - VERY GOOD STUDY OF TETRIS, WHICH SHOWS HOW MOVING THE BLOCKS AIDS COGNITION - EXTENDS THE MIND.

↳ Knappett's chapter is good for discussing situated action of making in response to the affordances of the material world. P. 48 'Cognition is both an internal and an external process'.

* It's better than it seems from this. I think the thing about Gibson is most useful.

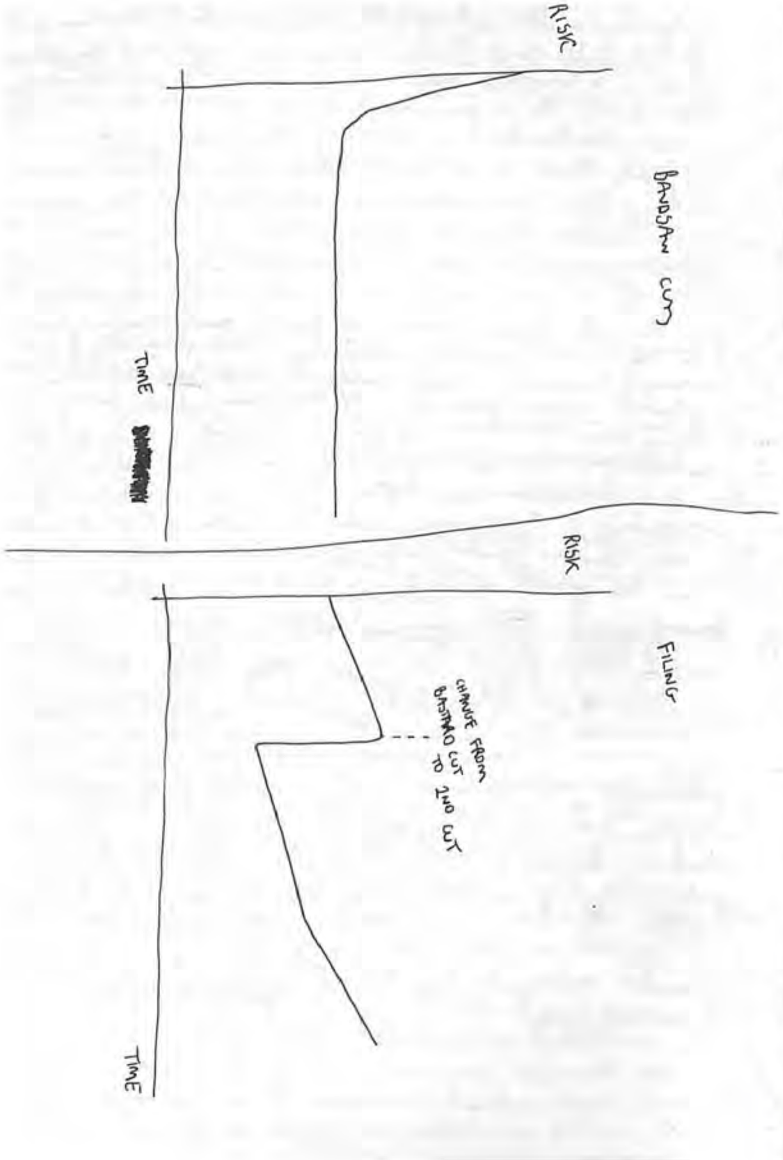
- I can use the jigsaw link to Bergson somehow. epistemic You could only speed it up if you removed all the just performed action + the pragmatic action $\boxed{\text{BANG}}$

Mauss in 'Techniques of the Body' (saved to anthropology making) uses the term 'habitus' to discuss a way of doing something (eg walking), which might be shared within a society.

LOOK UP (maybe) 'Doing Things with Things' ebook in uni library - Alan Costall

- P. 546 - '[i]s The point of taking certain actions, therefore is not for the effect they have on the environment as much as for the effect they have on the agent.'

FROM KIRSH + MAGLIO'S TETRIS PAPER - Link pragmatic + epistemic actions with diamond filing + the 'trace' left by a tool - tools have both pragmatic + epistemic purposes - they 'feedback'. * - AND THEN MAYBE ATTENTION TO THIS CAN HELP WORK WITH RISK + REWARD.



I learned - How does someone make something well?
10 - RISK / REWARD / TOOL CHANGE GRAPH
- CORRECT TOOL USE - 'MAKE EVERY HAMMER BLOW COUNT' - MAKING IS CUMULATIVE
OT - DEGREE OF FREEDOM (TENSION) - STAGES OF PRODUCTION - CUMULATIVE
5 - RESISTANCES - DEXTERITY - LASER CUTTING / USING A RULER 'SYMMETRY' HAND AXE
- EPISTEMIC + PRAGMATIC ACTION - DEXTERITY

INTERNAL EQUIVALENCE IS THE RESULT OF RHYTHM - IS THIS WHY IT BECAME VALUED?

-

4 OF Tim Ingold's LINES for discussion of 'traces' movement' and woven lines.

-3 - Uses Pye to discuss using a ruler as a jig + the that there is still risk involved (the angle you the pen, the condition of the ruler edge etc) But he doesn't discuss degrees of freedom and the risk the start and end.

- Ruskin quote - 'A great draughtsman can draw every but a straight one' - From 'The Elements of Drawing' (1904 ORIGINAL DATE), reproduced in 'The Works of John Ruskin, Vol. 15'; Cook + Wedderburn.

-

, I just carry on reverse-engineering things? NO
d I categorise the making projects into forming, joining, cutting, ...ing? YES. A study of techniques.

n Issues Paper - Dexterity as in response to the emergent conditions + a task.
g as dexterous activity ~~From that is situated~~ Dorst shows how there might be rethinking as design situation

p.10 of Dorst's DESIGN PROBLEMS + DESIGN PARADOXES, he describes - Dorst uses these to describe conflicting aspects/dimensions of a design problems + solutions co-evolve - this is a bit like ...ity in that one learns how to solve a problem over + again, not the solution. '...we cannot presuppose that ... is something like a set "design problem" at any point the design process'.

P.11 - Uses Suchman + Dreyfus to introduce situated action, describing design as situated action. Dreyfus describes 'breakdowns' which, as interruptions to routine problem solving and the moments of real choice that are critical in design. This narrows the idea of the 'design problem' to only those situations where routine problem solving has failed. I would say that these situations are very common whilst 'making', ~~often~~ they might be considered to happen during every 'epistemic action'. I don't know how Dreyfus categorises routine problem solving...
IS THIS DEVELOPED VALID FOR DESIGN ONLY OR FOR BLACKSMITH (WORKMANSHIP) + HAPPENS AT BREAKDOWN?

LOOK UP Dreyfus 'Intelligence without Representation' in Phenomenology and the Cognitive Sciences. —
... but I think it's similar to the problematic situations Suchman describes.

- The fledgling theory Dorst offers, in which there is no 'whole' design problem, just design situations, is very similar to Alexander's way of creating life that sees making as a form of growth. And my work on making could use these as strong references.

Design Issues Paper

~~In his Dexterity is The nature of dexterity is the The rhythmic blows of a blacksmith's hammer~~
~~In a study of The path of a blacksmith's hammer ... is controlled with ... consistency.~~ ~~As the smith's most fundamental tool, in an expert's hand it can~~ Used to forge hot iron on or against an anvil, ~~in an expert's hand~~, the expert's hammer can thin, thicken, shorten, lengthen, narrow, spread, cut, pierce, split and bend material (p.43 of Keller) ~~with~~ rhythmic hammer blows ~~must~~ that ~~achieve these~~ perform ~~these~~ transformations. In the time it takes for iron to cool, at which point the material must be

ed to the smith's fire and reheated. ~~the demands of constrained~~ time with which a blacksmith has to perform
e iron is, therefore, always constrained by the loss of heat. ~~This~~
~~int~~ To

ren Ratto is based in Toronto + writes a lot about 'critical
ng' + maker culture ~~for the~~ coming in social science background
nes of workshops etc.) (platitudes).

ED ACTION - NOT JUST SPATIALLY, BUT TEMPORALLY - AN ACTION
A DURATION, NOT SOMETHING THAT COULD BE SPEEDED UP, LIKE THE
MBLY OF A JIGSAW PUZZLE.

up 'Art + craft' section of Collingwood's 'The Principles of
for elaboration on Pye's distinction + tracing of it to
ce. See in ~~the~~ particular p. 20-1 for bit about crafting
s, Collingwood seems to fail to see poems as made
'words' - LINK with quote, poems are made from words
ideas.

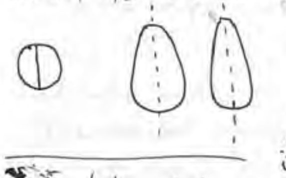
. 'The Timeless Way of Building', Alexander talks
: the flower + the seed (p.157-166), to discuss
'the quality' (of living structure) can only be
n, not designed and made. ~~Also~~
. - On the Samoan canoe carvers - 'Here there is no
ry of unnameable creative processes: only the patience
craftsman, chipping away slowly; the mastery of
is made does not lie in the depths of some
etrable ego; it lies, instead, in the simple mastery
the steps in the process, and in the definition of
e steps'.
s goes onto say that, like the genetic code in
eed, human building needs a guiding code. He

proposes the pattern language as a version of this that
ordinary people can use - just as they construct endlessly
unique sentences with their ~~every~~ ordinary language,
they can create living structure by applying + combining
patterns ~~languages~~.

\ ARE my guiding principles the pattern language,
or some sort of dialect, shared (as ~~the~~ Alexander's pattern
languages are shared + developed throughout history) amongst
a community of practice / practitioners within a discipline.
And this lets them work without 'ego' + 'chip away'
~~through~~ to master the process. If this is the case, ~~do~~ should
I identify the 'pattern language' for 3D printing, or
laser cutting. Do the languages I'm describing develop
in response ~~to the~~ / alongside / in sympathy with the
techniques of a particular trade / craft. I don't think I'm
writing on languages. maybe just punctuations?
- Also in Alexander, 'Timeless...', p. 537 - Chris talks
about how life is created effortlessly when people don't
'care' what others think of them and just act in a
comfortable way. This is a bit at odds with Pye's 'care,
judgement + dexterity'. Chris argues here that this
is essential to get away from ego-driven, image-based
architecture. It's about doing things for yourself, without
considering how it might be perceived / interpreted by
others; unlike Dr Spiller's interpretation of the pitt axe as a symbol of trustworthiness.
very much like a craftsman is in a state of
'flow' or obsessive like Sennett's craftsman. Doing it
for themselves, first + foremost. This is not necessarily
selfish, it's just free from considering a 'market' or audience,
which is perhaps the primary concern of modern architecture -
that modern outlook is not philanthropic, it's ego-driven, so
too maybe even ~~problem~~ 'problem solving', bespoke design.

...d 'WITH' handaxes before thinking 'about them' + 'THINKING ABOUT THINKING'. Basically, as an ...ognitive archeologist he's interested in human ...tions and what it means to be human.
- 'In other words, my claim is that the ...r had to learn first 'how' to make a symmetric ...axe before she/he could identify what symmetry parameter of human design dictates was', LOOK FOOTNOTE HERE TOO.

...METRY AS THE STARTING POINT?



So, if they were going for symmetry, they were miles off by modern standards. Does this mean a handaxe is of bad workmanship? Most would not subscribe to that, would they, because we acknowledge it given the resistances of the production process.

* ! * VERY IMPORTANT

...OP - 'The Art of Not Making' - for discussion of new ...tacit / action relationship. A bit like what Adamson says ...ut craft + art.

...UP JOHN SUTTON'S STUFF - saved in 'Anthropology - Making' ...r. He discusses skill + cognition, arguing for ...distributed models of cognition. His most recent paper ...I've saved has a good ~~bit~~ ending on working ...response to changing conditions, arguing against ...much of an explicit or internalised relationship ...een memory + skill - BASICALLY a really good ...k to Bernstein's stuff on dexterity ...tion, although he doesn't put it like this, ...s concerned with the relationship between

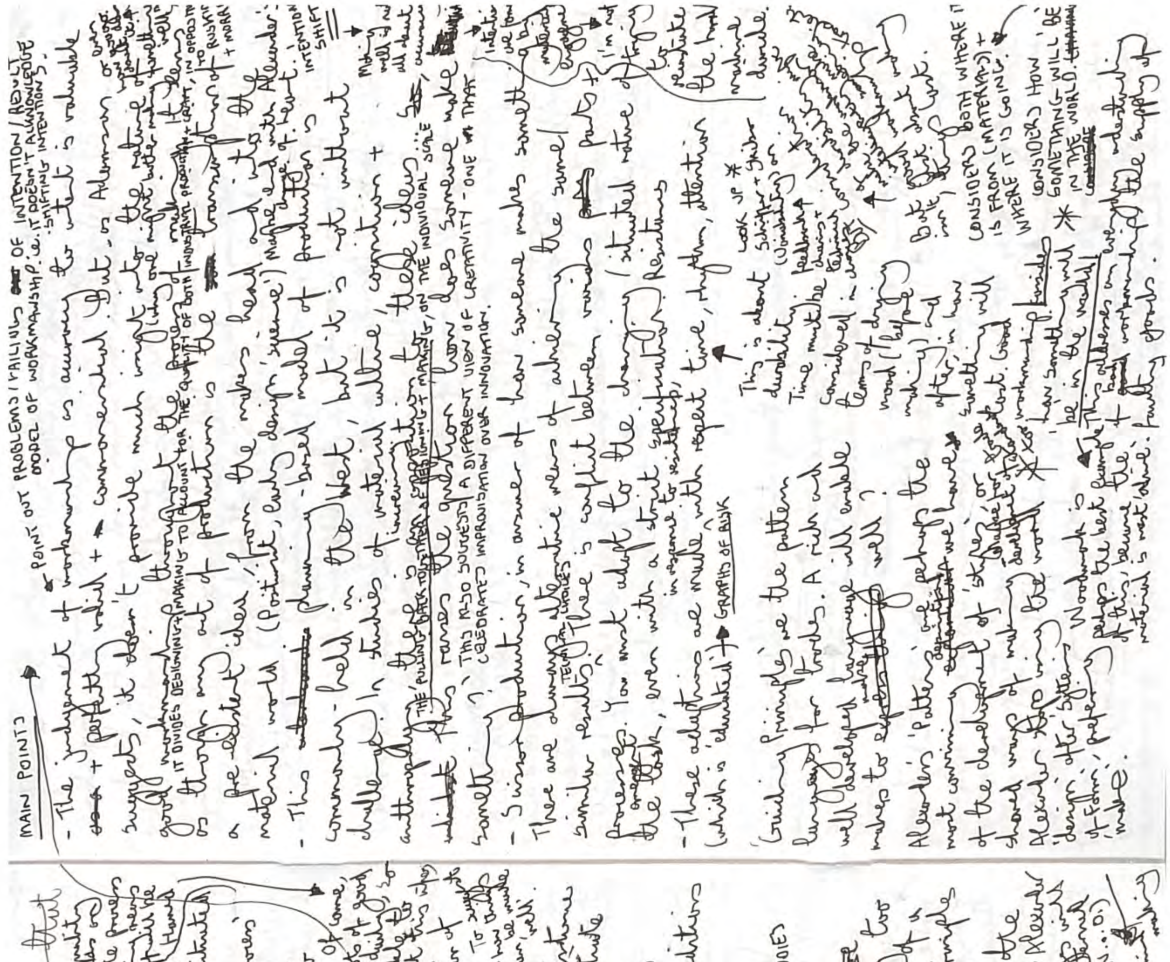
tacit + explicit knowledge during situated action. He ~~advise~~ advises against a 'widely dualistic scheme' (p. 772 of the cricket paper), in which there is a sharp distinction between knowing + doing, as often described by accounts of doing where people ~~do~~ are not helped by too much thought (the how cricketing folklore suggests a batsman ~~most~~ will not be successful if he thinks too much). Ingold talks about this too, in his chapter on tacit knowledge in 'Making'. Sutton counters the dualism with the evidence that even experts are known to recite fundamental principles as an aid - A GUIDING PRINCIPLE in my and the Kellis assessments. - On p. 773 of the cricket paper he uses the example of David Sudnow's study of learning jazz piano to show how these principles can come to make more sense to the expert than the amateur, as they 'tune' + 'reshape' 'grooved routines'.

* DEFINITELY ALSO SEE p. 203-4 of CLARK'S BEING THERE for his discussion of how GUIDING PRINCIPLES (AFTER KIRSH ...) - PERFECT LINK

LOOK UP David Sudnow's study of learning piano

Everyone can imagine trying to bash rocks together to make a ~~razor~~ sharp edge. We ~~~~ actually judge workmanship with reference to our own experience of the material world + there can be no definitive judgement of workmanship with reference to intentions. We make allowances for the production process. We know that absolute symmetry was never intended. Pye describes how 'rough' finishes are often of very good workmanship + I think this is accounted for by the skilful negotiation of resistance.

WHAT A LOAD OF SHITE



MAIN POINTS

← POINT OUT PROBLEMS / FAILINGS OF INTENTION / RESULT MODEL OF WORKMANSHIP. i.e. IT DOESN'T ACKNOWLEDGE SHIFTING INTENTIONS.

- The judgement of workmanship as accuracy to intent is valuable + perfectly valid + commonsensical. But, as Adamson suggests, it doesn't provide much insight into the nature of good workmanship throughout the process of making. It seems as though any act of production is the transmission of a pre-existent idea, from the makers head and into the material world (Positivist, early design 'science') Maybe end with Alexander's image of heart.

IT DIVIDES DESIGNING + MAKING TO ACCOUNT FOR THE QUALITY OF BOTH INDUSTRIAL PRODUCTION + CRAFT, IN OPPOSITION TO RUSKIN + MORRIS

- This planning-based model of production is commonly held in the West, but it is not without challenge. In studies of material culture, cognition + anthropology, there is increasing opposition to these ideas. THE PULLING BACK TOGETHER OF DESIGNING + MAKING, ON THE INDIVIDUAL SCALE. This raises the question how does someone make something? THIS ALSO SUGGESTS A DIFFERENT VIEW OF CREATIVITY - ONE THAT CELEBRATES IMPROVISATION OVER INNOVATION.

INTENTION SHIFT

- Scissor production, in answer of how someone makes something. There are always alternative means of achieving the same / similar results. There is conflict between various parts + processes. You must adapt to the changing / situated nature of the task, even with a strict specification. Resistances

- These adaptions are made in response to resistances, with respect time, rhythm, attention (which is 'educated') → GRAPHS OF RISK

'Guiding Principles' are the pattern languages for tasks. A rich and well developed language will enable makers to make well?

Alexander's 'Patterns' are perhaps the most convincing definition we have of the development of 'styles' or shared ways of making developed for trade. Alexander opposing the word 'design' after 'Synthesis of Form', preferring 'make'.

Woodwork is perhaps the best example of this, because the material is most 'alive'.

This is about durability. Time must be considered in terms of drying wood (before making) and after, in how something will last. Good workmanship considers how something will 'be' in the world! This addresses an everyday understanding of bad + good workmanship i.e. the supply of faulty goods.

LOOK UP * Schiffer + Skibo (Windsor) on feedback, choices + technical

But good workmanship is not about making it, it's about things that last.

CONSIDERS BOTH WHERE IT IS FROM (MATERIALS) + WHERE IT IS GOING.

* CONSIDERS HOW SOMETHING WILL 'BE' IN THE WORLD.

Making well is not all about intention, we found ... I'm not trying to reinstate the hand machine divide.

develop a description of good workmanship that describes the process of making

How does someone make something well?

WHY'S THIS IMPORTANT? The quality of the material world depends on it, a flawed understanding of the process of making means we make stuff that will be ...

adapts to changing conditions of an emergent task. i.e. distributed cognition / situated action. Hand; Rhythm; Guiding principle (pattern languages); Education (Gibson 'Education of Perception'); Material; Practice; Finishing things off. The 'process'

might critique a few objects (like the bench, to ...) dismissing workmanship) AHA, isn't this craftsmanship? Of course, lots of good stuff is made digitally, so it's not impossible to make well without the hand like Alexander's.

Problems of intentionalist accounts — Ingold, Pelton, Malafouris etc.

Scissor making dimension → WHY?

How does someone make something well EXPERIMENT?

WHY? TO contribute new description of workmanship. TO suggest how things can be made 'well'.

DOES THIS LEAVE SPACE FOR ANTICIPATION / FORESIGHT?

So I can start to identify types + rhythms + ways in which people skilfully negotiate

So I can develop the idea that good making is characterised by adaption to the changing conditions of a task.

DEVELOP PYE'S IDEAS ON WORKMANSHIP, WITH REFERENCE TO RECENT MATERIAL CULTURE STUDIES

* Alexander's pattern languages are about design stage than. don't say too much about the 'low-level' specifics of a task. But maybe his 15 fundamental principles do?

all about where / how you distribute 'control' throughout the production process.

p. 546-7 of 'Timeless Way', Alexander shows that pattern languages will always evolve, there's no eternal 'right'. But he does (in N.o.O.) consider there to be a 'right' process behind making

CATHEDRAL — MASTER MASON — BUILDER

SCISSORS — DESIGNER — 'FACTORY'

2 PAGES OF SENNETT'S CRAFTSMAN - Good stuff on
.. during the process - epistemic + how this can be
.. (i.e. stop to think about the tools we're making) Here
.. really makes his point about the connection between hand
.. + 'making is thinking'.

... P.74 - Pye's Blue book 'It is never easy to say
.. workmanship begins and design ends, for the simple
.. that workmanship is design. Nine people in ten
.. suppose that the good or bad appearance of things
.. on their design alone. ~~Their idea is that~~' ...

BLUE BOOK OF PYE - Is about knife + axe that stay
.. forever. - It's possible to design things that don't
.. + nothing ever really works.

.. PICKERING'S 'Beyond Design: Cybernetics, biological
.. tes and hylozoism' is saved in 'Interesting Things'.
.. a dimension of cybernetic controlled robots etc.,
.. contrasts 'Modern' approach to technology (control
.. + knowledge of nature) and cybernetics, i.e.
.. what's available in nature to compute. Possibly
.. to drives a 'craft' approach to making things,
.. + working with nature, not against it.

.. Luke Feast's 'A problematic approach to the science of
.. design' - Refs. Deleuze's ... approach (P.373 of D+G, 1980/87) - that 'follows the flow of matter' by "subordinating all operations to the sensible conditions of intuition and construction".
.. distinguishes between design processes that 'reproduce' or 'follow'

MY THESIS - Because of all the work about ... (D+G, Delanda etc.), ~~we could do~~ material engagement (Knappett, Malafouris, Renfrew etc.), we could do with a study of making techniques + advice doesn't have to behave like artisans. This requires studying the techniques of making in low volumes. || WORKMANSHIP!

LOOK UP 'Towards User Design' John Redström - BRILLIANT ... for 'Tools for Everyday Life'. 'SAVED IN 'INTERESTING THINGS'.
+ His other paper 'RE: Definitions of Use' is also interesting, but makes the mistake of thinking ~~'finished' things~~ things need to be designed as 'unfinished' - i.e. failing to recognise that nothing's ever really finished - The idea of maintaining tools (not helping to 'create' a DO-HIT Chair) is useful here.

LOOK UP Delanda 'The Case of Modelling Software' - Saved in hylomorphism (1 ...) P. 139 - Talks about specifying a spline in a programme + the ideal of using fewer nodes - linking this to working 'with' a material + allowing it to follow the smoothest path.

GREAT  Thee we, of course, new 'guiding principles' in digital stuff.

LOVELY LINK Between the Klee quote Ingold loves ('Art ~~doesn't~~ does not reproduce the visible, but makes visible') and Alexander's description of structure preserving transformations + the 'fuzzy' that surrounds a latent center.

...ON 'JIGSAW' BIT is P.340 + It's discussed in 'Creativity + Cultural Improvisation'

...UP Chapter 5*: The exteriorisation of operations' of
...'s 'Tools for the Hand, Language for the Face' paper
...n is an 'Appreciation of Leroi-Gourhan's Gesture and Speech')
...similar type stuff ~~about~~ as my epistemic techniques + about
...e-pointdrawing the same equivalence between human handling
...ols and machine operations. Like the hands are the recipients
...structions just like a machine. - DO my examples of file +
...inder fit into one or two of Leroi-G's categories of tools?

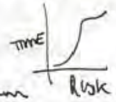
THE WORD 'Latent', like Alexander uses it to
be bringing out latent potential in something, to
...ify a centre. This could be combined with Ingold's
...ting foresight. P.372 of Book 2 is very good for

...SITED PRODUCTION etc. ; SKILL / DEXTERITY ; PLANNING / SITUATED ACTION ;
...MANSHIP ; MATERIAL ENGAGEMENT ; INNOVATION / IMPROVISATION ;
WORKMANSHIP ; 'KNOWLEDGE'
'THE GOOD WORKMAN' 'THE DESIGNER + THE WORKMAN' 'MAKING THINGS WELL'

...'Workmanship-in-action' - The use, judgement and dexterity
...making + ~~to~~ what can be learned for design. 'HOW DOES SOMEONE MAKE SOMETHING WELL?'

~~...unity of designing + making~~

...ing from drawings that don't specify 'steps' of
...(see P.117-8 of Keller) relies on knowledge. 'We are of the ... these steps.
...of curve covers practice



FROM KELLER'S BLACKSMITHING - P.18 suggests that
knowledge is dexterous in the same sense of
adapting to changing conditions of a task,
just as ~~...~~ 'tacit skill' is. And you build knowledge
in a similar way to skill.

LOOK UP FOR METHODOLOGY - L.S. Vygotsky, mentioned on
P.19-20 of Keller's. - Book is 'Mind in Society'... They
suggest P.61 about tool use.

My Design Issues paper is about how design should acknowledge
that tools + techniques are not just pragmatic, but also
epistemic. It's sort of about craft + design. Maybe about the way
the tools + techniques of craft design and learning, but the
processes of design do not?

Book about tools

Intro ; Dexterity 'Tool use' / skill ; Tools that reward sensitivity to feedback; Could be touch, visual or sound, immersive.
Epistemic tool use (not just 'functional' objects) - but with the diversity
, a la P. the idea of a tool's function + divisions - specialised + non-
specialised tools. - Learn about the world through tool use. - NOT JUST SUCCESSFUL FOR THEIR EFFECT IN THE WORLD

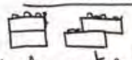
LIKE Knott's PhD contributes all his 'unravelings' about model
railways + paint-by-numbers etc. + then uses it as evidence to
build a more general one, MY PhD uses the practice of design +
making to probe the issues, presenting new objects + analysis
as ~~as~~ evidence to support broader points.

-em - Designing can be separated from the process of
-ing.

-duction must set out the theoretical basis for my
-). Drawing on the work of others, I'll describe the
-nges being made to intentionalist accounts of production,
Cartesian divide between people + things, the
-ministic, 'assemblist' view of making as opposed to the
-nty of growth etc. My focus will be on workmanship,
use this work to justify my focus on improvisation +
-zed for a better understanding of 'craft' + how this is
~~add~~ useful for making things well.

I. INTRO
- Workmanship - Material Engagement Theory
- Hylomorphism + Morphogenesis
- Lego + the Gothic
II. HOW TO IMPROVISE / MAKE THINGS
- Tools, techniques + the extended mind
- Step-by-step, guiding principles
- Tradition
III. CONCLUSION / DISCUSSION
- Digital fabrication
- Process
- making it up when designing

DISASSEMBLY
- Semper + the ornament analyst.
- MAKING + GROWING
- AMBITIONS FOR DIGITAL FAB.
- INSTRUCTIONS


LEGO + GOTHIC


~~One of the most enduringly popular toys of the 20th + 21st centuries, Lego~~
~~Lego pieces The Lego™ system bricks allow people to assemble~~
~~self-supporting structures can be fitted together in combined~~
~~to make~~

This section will ~~consider~~ explore the role of precision in making. ~~Contrasting~~ Comparing LEGO ~~bricks~~ assembly ~~with~~ and the construction of Gothic cathedrals, I will continue to contrast the two understandings of making outlined above. Precision in the assembly of LEGO bricks is ensured by the design of the components - they snap together ~~[illegible]~~ with a high degree of accuracy. David Turnbull's analysis of gothic cathedral building ~~also~~ attributes the possibilities for successful structures to lie in the precision with which individual stones can be cut and ~~therefore~~ fitted. Both systems rely on accuracy at the local level.

Lego + Gothic Cathedrals

will use the examples of Lego structures + Gothic cathedrals to help illustrate the differences between two ways of making *

~~successful Lego structures depend on the self-alignment of the system.~~ Flexibility – just two eight stud blocks can be combined in a total of 24 different ways.

The examples are chosen because a) Lego has been used by proponents of digital fabrication as a prototypical digital material, or one with digital properties. b) The building of Gothic cathedrals took place in a time when divides between head + hand, function + ornament, designing + making were less entrenched. It therefore offers us a example of an alternative, one which has recently been celebrated by digital manufacturing / design advocate, architect Lars Spuybroek.

I consider the differences + similarities between Lego assembly + cathedral building in an attempt to offer greater insight to both the modern and medieval perspective on making.

I might also think about these in terms of workmanship. good/bad risk/certainty

· Popular, in part perhaps because of the flexibility – you don't have to stick to just the suggested model. Tied up with post-war narratives about how creativity in childhood (ref. Ogata) can be fostered. Ever popular in designers' Architectural model

One may following the intentions or build a model without reference to them. (FIG. showing my experiments)

In either case, the structural integrity of the Lego model is a consequence of the self-alignment of the Lego pieces. Since 1957, the Lego system has fitted itself.

Gershenfeld on how this allows construction to be precise, beyond the limits of dexterity of a child. It is, for Gershenfeld, p.5 the prototypical digital material, assembled with certainty + disassembled with ease. 1. Accurate map 2. Define their own spacing – any size possible 3. Different materials 4. Disassembly

- In a similar way to how the Lego relies on the precision of their fitment, David Turnbull has shown that the remarkable structures of Gothic cathedrals are a consequence of the precision with which individual stones were cut.

- Turnbull addresses the question of how, without centralised control, theory of mechanics and throughout sporadic periods of decentralised building, Gothic masons were able to produce stone buildings of enormous scale... Variation – Pre existing design vs.

- In both Lego + Gothic we see how localised precision / Lego instruction accuracy + fit can lead to global integrity + variation.

- BUT there are differences in the way they're (formed) (Disassembly / Growth) (Spuybroek vs. Gershenfeld) – LEGO IS ASSEMBLED, CATHEDRALS GROWN

- Architect Lars Spuybroek sees in Gothic architecture a fundamentally digital system. (Quote from Chapter 1 of Sympathy). In the bundles of ribs, he sees an architecture of variation that is generative + could be coded.

- But, as Turnbull shows, these are not buildings that ~~developed~~ were built according to master plans. The code is not all there at first.

- There aren't overall symmetries (front of Notre Dame), just local fits.

Lego is assembled from pre-existing parts. It may, in Bergson's terms, proceed at a faster + faster pace, it is like jigsaw assembly. Gershenfeld, programmable material should rapidly a finished structure. It is not a product of the time taken to build it. Cathedrals, on the other hand proceed in step-by-step transformations. They are grown. They exist in time.

This difference is perhaps most telling when it comes to disassembly. A Lego model can be taken to pieces, even recombined to form a totally different structure. This, Gershenfeld states *

IAL NOTES.

UP CARL MITCHAM, WHO INGOLD QUOTES ON P.61 OF 'BEING

' - 'At the core of technology,' there seems to n desire to transform the heuristics of technique ~~dog~~ algorithms of practice' (1978: 252)

Lando's 'The Core of Modelling Software' is a great source for the two understandings of the 'genesis of n'. I think it's good for my introduction, as it s the door for an investigation of the improvisational re of workshop practice - he was the idea of blacksmiths, carpenters etc. to ~~spell~~ describe how le have worked with heterogeneous materials, then on to discuss how this is now a developing area the realm of virtual materials. He says designers have to become adept at designing 'embryos' or ' for buildings that can then be steered through tion-like generative processes in the software, ady their final form. He says that this will unlike dealing with relatively obedient solid polygons in software. My contribution is to look at the provisatory nature of workshop practice in more ail, to help develop ~~for~~ the understanding of designers who make things up - 'Real' materials not obeying forced like this.

THE TOOLS + MATERIALS: ILLUSTRATOR'S PEN - THE CHISEL ... HAMMER / FILE - DOORES - MATERIALS INDICATE HOW THEY SHOULD BE WORKED.

- MAKES YOU DRAW SMOOTH, BECAUSE OF ~~THE~~ THE WAY OF DRAWING
- MAKES YOU THINK OF LINES AS JOINED UP DOTS / NODES.

As we have observed in the previous section, the productive capacities of tools + materials are vital in the improvisational nature of workshop practice. ~~Here~~ Now we consider how ~~exactly~~ the properties of tools + materials might influence the development of form, using the example of drawn from computer design software - the 'Pen' tool of Adobe Illustrator. IS HENRY FOCILLON RELEVANT HERE? This example is ~~typical of CAD software, in that~~ ~~because~~ it is ~~both~~ an instance of a virtual tool working upon a virtual material. Clicking and dragging with the pen tool allows practitioners to draw two-dimensional lines. These lines may be ~~both~~ curved ~~and~~ or straight-edged ~~These lines~~ and are specified, like the Nurbs + Beziers of all CAD software, by the points that they connect. What we draw with the 'pen' tool is not a line but a series of points that the software then converts into a line. These points may be endlessly edited inside the software - more moved, raised, added and deleted - ~~without~~ and the lines which connect them will transform instantly ~~in accordance~~. ~~Thus~~ These points, or 'anchors' using Illustrator's terminology, may be considered analogous to the co-ordinates on a graph. They are specified mathematically, and the lines we the vectors of their relationships. The advantage of this format is that * (FROM ABOVE) Unlike bitmap images, ~~which~~ which consist of a finite number of pixels that can appear pixelated when stretched, vector lines may be edited without a loss in quality. So, if a logo is created at It is possible to draw a line or shape in Illustrator (~~nodes~~) at one size, it may be scaled By ~~relating~~ lines to the connections between points, a vector-based drawing software provides an environment that

~~y Things Up: Improvisation in Workshop Practice.~~

~~ter ? : Filing + Linishing 'On Wasting Steel'~~ - EPISTEMIC ACTION

* FOR THIS TO WORK, I MUST HAVE ALREADY MADE THE CASE THAT 'MAKING' IS NOT JUST THE REALISATION OF AN IDEA.

Tools for 'epistemic action'/ finding things out. Tools of discovery

REF 'Constellations for action', Keller

~~There are usually more~~

There are often a variety of tools and techniques that may be used to achieve the same results. ~~are what Stiles + Shiffer (ANTH. PERS. ON. TECH, P145) call 'technical choices' of production, those 'decisions made [in] product manufacture that determine the item's properties'. The chamfer on the drawing block, in the drawing above, for example,~~ Take, [for] example, the chamfer on the block in the [drawing] above. Were this chamfer to be ~~made from~~ ~~the chamfer~~ removed, or 'wasted', from the [block], there are a variety of tools and techniques [tha]t could be employed. The angle could be cut on [a ha]nd saw, or with a hack saw, ~~or machined using~~ [a m]illing machine. If it is sawn Any ~~the marks~~ unevenness [from] these cutting processes could be removed using a [han]d files, or power files, or a belt linisher ~~or~~ [emer]y paper. Alternatively, the ~~---~~ chamfer might [be] machined using a milling machine, whereafter any remaining tool marks might be removed using emery paper. ~~To select from these options~~ The ~~process~~ techniques to be used will be chosen with reference to the available tools, the condition of those tools, time, degree of accuracy required and habitual practices of a practitioner ~~(Keller, 1977)~~, as they develop a constellation for action (Keller, 1977).

THIS MOVED TO START?

Whilst such decisions will affect the item's formal properties to some small degree (for example, ~~---~~ ~~applying the tool finish~~ finishing the part using a belt linisher will likely result in a more linear pattern of scratches on the object's surface than finishing with hand-held emery cloth), ~~by hand~~ we can take it that, for practical purposes, with due care and attention, ~~simple~~ ~~jobs~~ results such as the chamfered block may be ~~performed~~ achieved using ~~------~~ a variety of alternative tools and techniques.

What I ~~hope~~ aim to ~~------~~ explore in this chapter, however, ~~------~~ is ~~the~~ not the capacity for ~~tools and~~ the various tools and techniques of workshop practice to achieve the same results, but their varying abilities to help a practitioner find things out along the way. Having acknowledged that there ~~------~~ is always more than one way to achieve practically identical results, I argue that this does not preclude us from considering what ~~---~~ else the techniques offer, beyond their results. This begins by introducing the idea of epistemic action.

[THEN SHOWING HOW APPLICABLE THIS IS TO MAKING/PROTOTYPING] THEN COMING BACK TO LOADS OF GOOD EXAMPLES + ASSESS THE OPPORTUNITIES OF DIFFERENT TOOLS + →

~~IC ACTION~~' PAPER for Jaygne (could say how many times he's been refed in this journal.)

... with Pye on Workmanship — 'The problem with Pye.' → submits to dualistic, hylomorphic view of production with mind/world distinction.

...t to discuss the nature of actions that aren't just ...atic + how the techniques / processes of production can ...t these. So it's an argument against the idea that ...y is merely the realisation of a pre-existing ~~#~~ design, ...is what Pye's version of workmanship ~~suggests~~ describes. 'With comes discovery.' Risky processes are epistemic. Certain ones are ...tic. This influences the practice of design enormously - how ...think the world should be made - so there is a more ...ntal distinction, ~~below~~ than that between craft + industry ...k + certainty, and that is between a world that is ...de step-by-step /improvised, or one which is planned in advance to execution.

Offer eg.s - like we don't consider the effects of computer software, we worry about the 'skill'. — How does this affect our design concerns -

UP - 'Embodied Cognition' Shapiro - ebook in Library

...troduce these ~~ideas~~ concepts (of epistemic + pragmatic ...l techniques) in a ~~way of~~ of which I hope ...l Pye would approve; with reference ...e practical business of ...g things.

Offering instead the framework of risk + certainty to think about the various methods of production.

Pye dished the illusory distinction of craft + industry, hand + machine. Here I attempt to show that there is a more ~~essential~~ fundamental distinction to be made, between a way of designing + making the world in an improvised fashion + one planned in advance

UP

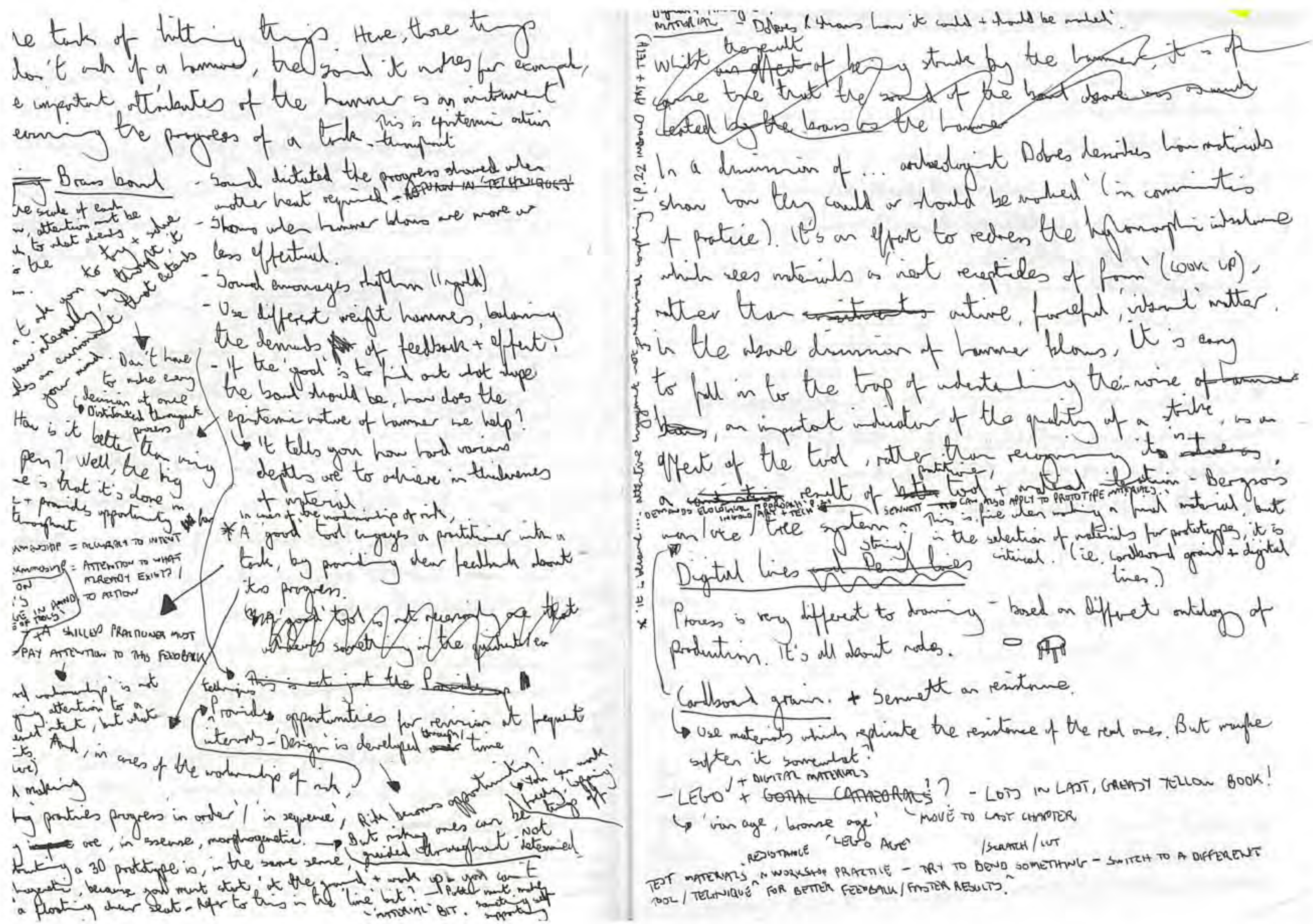
GICALITY' JOHN McCARTHY + PETE WRIGHT.

- CONSTRUCTIVE DIALOG BETWEEN PYE + 'MODERN' THOUGHT.
- SCAFFOLDED BY DOING

'The Problem with Pye'

~~Book~~ The woodworker, furniture designer, naval architect and Royal College of Art professor David Pye provided those of us who like to think about craft with what might be (craft theorists) considered a foundational text. In 1968's The Nature + Art of Workmanship, Pye ~~...~~ ~~...~~ ~~...~~ directed his attention to debates about 'hand' and 'machine' work, skill and craftsmanship ~~...~~, bringing a logic and clarity to matters he considered muddy fuzzy. The importance of Pye's contribution is clear. In this Journal's six volumes, ~~...~~ The Nature and Art of Workmanship has been referenced x ~~...~~ times. In contemporary reappraisals of crafts value, David Pye's ideas are key reference points (REFS) + in broader anthropological + archaeological (REFS) enquiry ~~#~~ on craft practice, Pye gives scholars much lucidity. All this is made extraordinary when one considers that the terms craft + craftsmanship were ~~disliked by Pye and~~ avoided by Pye almost altogether, disliked + dismissed by him on the grounds of their association with. apart from their dismissal by their association with the 'xxx' thinking of Arts + Crafts. It is, rather, Pye's alternative conceptions of the 'workmanship of risk' + the 'workmanship of certainty' that have, ~~cutting through what Pye considered 'double-talk' platitudes~~ enduring appeal. In this paper, * I ~~seek~~ hope to show that Pye's writing on ~~of~~ workmanship, whilst presenting an appealingly straightforward, lucid / logical + apparently timeless / uncontroversial discussion of human production is, in fact, based upon a potentially flawed orthodoxy ~~...~~ regarding the question of 'how things are made'. In this discussion of

* DESCRIBE RISK / CERTAINTY HERE? ~~I provide~~ offer a mild / modest distinction


e task of hitting things. Here, there things
don't only of a hammer, the sound it makes for example,
e important attributes of the hammer is an instrument
examining the progress of a task. This is epistemic action
throughput

Brass bowl
- Sound dictated the progress showed when another heat required – ~~MENTION IN 'TECHNIQUES'~~
- Shows when hammer blows are more or less effectual.
- Sound encourages rhythm (Ingold)
- Use different weight hammers, balancing the demands of feedback + effort.
- If the 'goal' is to find out what shape the bowl should be, how does the epistemic nature of hammer help?
- It tells you how hard various depths are to achieve in thickness of material.

How is it better than using pen? Well, the big thing is that it's done in throughput
Don't have to make every decision at once
Distributed throughput process

In case of the workmanship of risk,
* A good tool engages a practitioner with a task, by providing clear feedback about its progress.

Provides opportunities for revision at frequent intervals – Design is developed through time

SKILLED PRACTIONER MUST PAY ATTENTION TO THIS FEEDBACK

And, in cases of the workmanship of risk,
making practices progress in order / in sequence; Rich becomes opportunity; But risky ones can be guided throughout, not determined
a 30 prototype is, in the same sense, a floating drawing. Refer to this in the 'line' bit? – 'MATERIAL' BIT.

MATERIAL – Dobres & shows how it could + should be worked.
~~Whilst the result of being struck by the hammer, it is of course true that the sound of the bowl above was sounded by the brass as the hammer~~

In a discussion of … archaeologist Dobres describes how materials show how they could or should be worked (in communities of practice). It's an effort to redress the hylomorphic imbalance which sees materials as 'inert receptacles of form' (LOOK UP), rather than active, forceful, vibrant matter.

In the above discussion of hammer blows, it is easy to fall in to the trap of understanding the noise of hammers, an important indicator of the quality of a strike, as an effect of the tool, rather than recognising it as an emergent result of both tool + material. Bergson's ~~use~~ / tree system: in the selection of materials for prototypes, it is critical. (i.e. cardboard grain + digital lines.)

Digital lines

Process is very different to drawing – based on different ontology of production. It's all about nodes.

Cardboard grain. + Sennett on resistance.
Use materials which replicate the resistance of the real ones. But maybe soften it somewhat?

– LEGO + DIGITAL MATERIALS ~~GOTHIC CATHEDRALS~~? – LOTS IN LAST, GREASY YELLOW BOOK! MOVE TO LAST CHAPTER
'iron age', bronze age' 'LEGO AGE' / SEARCH / CUT

TEST MATERIALS, RESISTANCE, A WORKSHOP PRACTICE – TRY TO BEND SOMETHING – SWITCH TO A DIFFERENT TOOL / TECHNIQUE FOR BETTER FEEDBACK / FASTER RESULTS.

~~ENVIRONMENT~~ - 'Epistemic action + Workshop environments'

can be organised to help improve 'cognition'.

~~could this~~ does this differ with on screen environments?

...ing looks like a nail when you're holding a hammer'.

...te' of hand tools presents a different approach to ...ation than a pre-determined CNC router.

...der's 'situated' architecture

This is also considered in Gunn's PhD - Chapter 1. - The architect's comparison of landscapes in CAD + in real life.

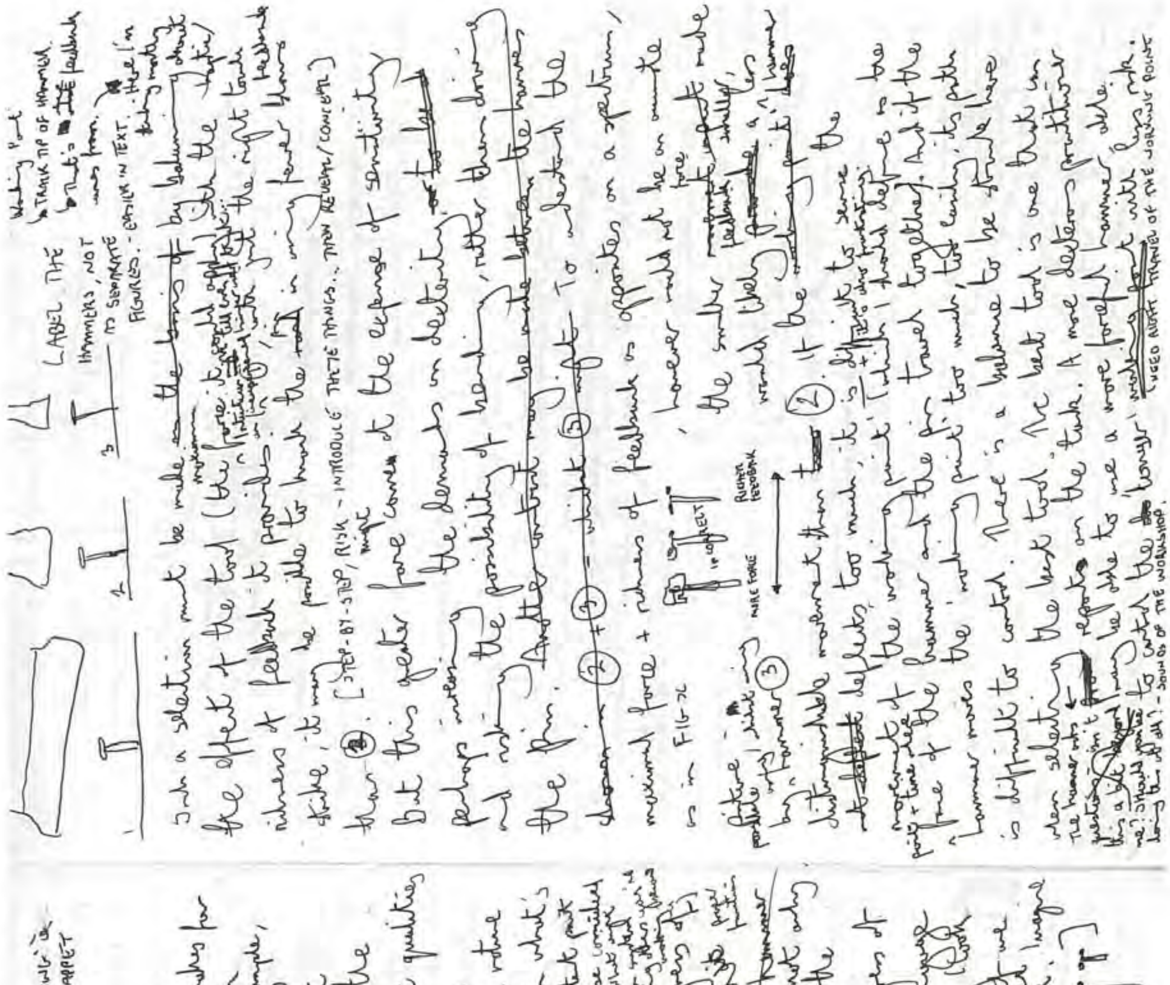
'On-screen' cannot be reorganised as simply as real-life ...hop - As Gunn writes (p. 132) - 'One of the main ...ms with incorporating CAD technologies into architectural ...n is that very few architects have the skills necessary ...programme a computer.'

TECHNICAL CHOICES / ...

The scalpel + the laser cutter

In order to explore the epistemic(?) implications of alternative tools and techniques, I compare the practice of cutting paper using a scalpel and using a laser cutter. Both techniques could be used to create practically identical results - whilst ~~a scalpel might be difficult to produce~~ it might be more time consuming ~~difficult~~ to ~~produce~~ cut shapes with a scalpel to the same degree of accuracy as a laser cutter, and the ~~cut edges might have a different quality~~ qualities of the cut edges do/would might vary, these differences, once acknowledged, ~~need~~ not affect the validity of this analysis. The concern here is to understand how the alternative techniques of paper cutting impact upon the design process. The main difference I wish to articulate is one of feedback throughout the process (i.e. how reflection is understood in terms of process / scale) + response to that feedback + the implications on the decision making process + a degrees of freedom thing, see you can lob a bit off later with a scalpel + the fact that one is directional. (I need to be clear that one is not 'better' than the other, they are just different philosophically)

You could argue that it would be better to compare the scalpel instead with the computer drawn line on the screen, or the mouse that is used to draw it, for it is here that you find the equivalent directional tracing of the form. The laser cutter simply follows a line already plotted by another, directionally ~~conceived~~ embodied


~~...or Context~~, Then reveal or conceal

...d Tools + ADD COSTALL (1997, 79) ABOUT 'TELEOLOGICAL REASONING' i.e. ASKING WHAT THINGS ARE 'FOR' - QUOTED IN P. 44 OF KNAPPETT

~~...people with a task~~ - What makes for a good hammer?

...ing to the context of hammer use, the nature of ...ed/dexterous practice allows us to consider what makes for a good hammer. Whilst a practitioner may consider a ...ty of criteria when selecting a purchasing/buying new tool - for example, its ...ility, aesthetics, cost, ~~complementary~~ how it might complement an existing collection of similar tools - the ... that dexterity is a sensitivity to the emergent qualities ... task offers an insight on the ~~the~~ question ... makes a 'good' hammer. Recognising the epistemic nature ... skilled hammer use leads us to consider the question what's ... hammer for? ... (...ation or fruition)... i.e. The sound it makes being an important part of that, even though it might not be considered for during the design phase ... a hammer is as much for reporting on the progress of ... task as it is for achieving pragmatic results ... ~~be said if we ask what is good for a 'good' hammer~~ ... ~~A ham~~ The quality of a hammer then lies not only in its efficiency at achieving goals, but also in the ... task it offers, as an instrument to measure the progress of ... those goals. Good tools help to sensitise and engage ... with a task. They give that 'sweet feeling' (Cook woodworking book). This point is made clear if we ... pragmatic effects / goal accomplishment ... the relationship between efficiency and feedback. Imagine ... choosing between a range of hammers [IMAGE ...] to knock a pin into a piece of timber.

LABEL THE HAMMERS, NOT AS SEPARATE FIGURES. - EASIER IN TEXT.

Working Point - TAKE TIP OF HAMMER. That's the feedback comes from. Here I'm talking mostly...

Such a selection must be made ~~in the terms of~~ by balancing the effect of the tool (the maximum force it could apply) with the tactile richness of feedback it provides. Intuitively ... with just the right touch ... feedback strike, it may be possible to knock the pin in many fewer blows than (2). [STEP-BY-STEP, RISK - INTRODUCE THESE THINGS... THEN REVEAL/CONCEPT] But this greater force might come at the expense of sensitivity, perhaps increasing the demands on dexterity, ~~or to bend~~ and risking the possibility of bending, rather than driving the pin. ~~Another contrast may be made between the hammers chosen in (2) + (3) - whilst (3) might~~ To understand the maximal force + richness of feedback as opposites on a spectrum, as in FIG x

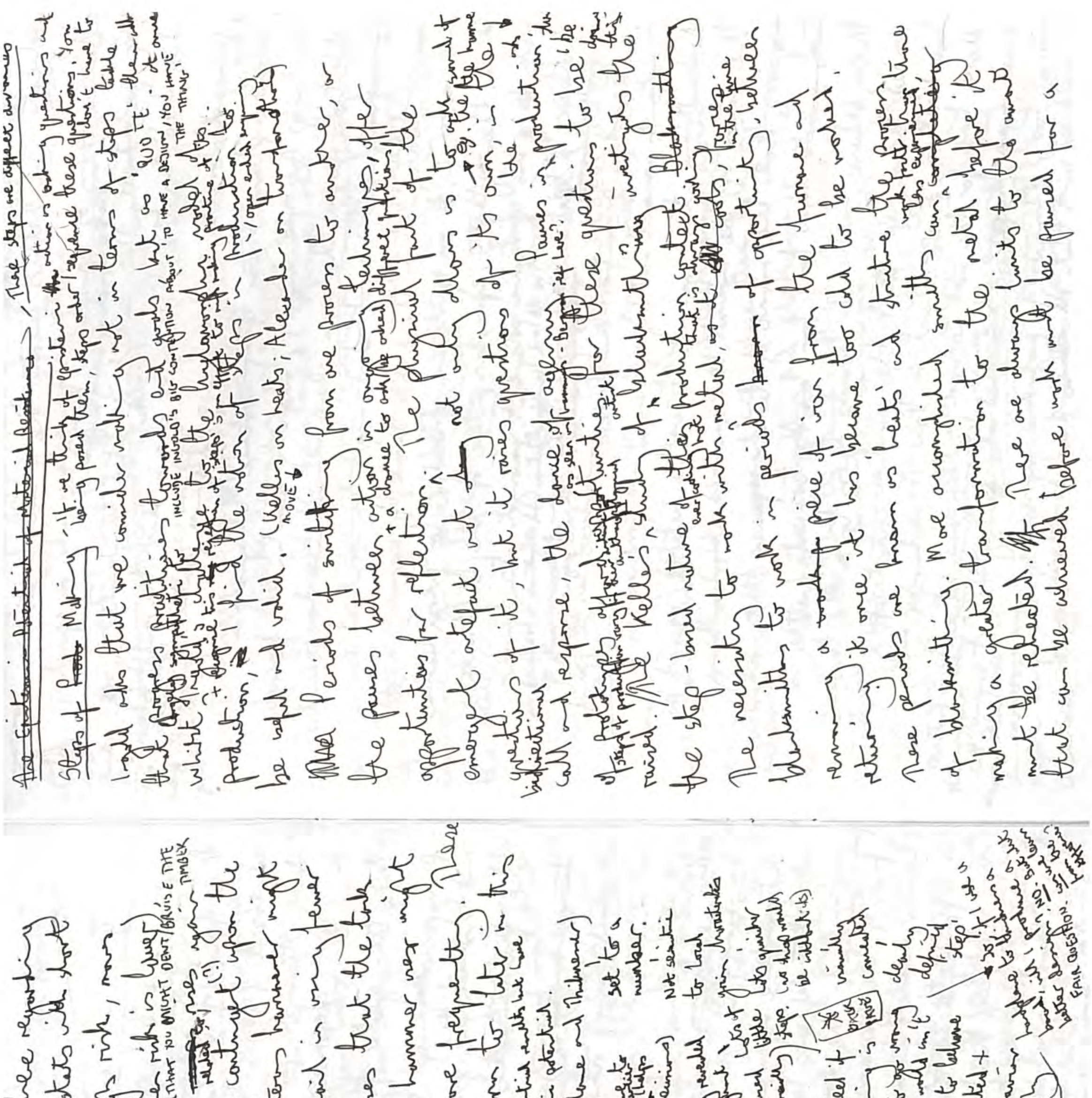
INCORRECT

MORE FORCE ⟷ RICHER FEEDBACK

, however would not be an accurate picture - ... striking by hammer (3) ... the smaller force made ~~smaller~~ feedback would likely ~~provide~~ a less distinguishable movement than (2). If the ~~working point~~ hammer ~~does~~ ~~deflect~~ deflects too much, it is difficult to sense the movement of the 'working point' (which I should define as the point + time where the face of the hammer and the pin travel together). And if the hammer moves the 'working point' too much, too easily, its path is difficult to control. There is a balance to be struck here when selecting the best tool. The best tool is one that can report on the task. A more dexterous practitioner may be able to use a more forceful hammer, able to control the 'longer' ~~working point~~ with less risk.

NEED RIGHT TRAVEL OF THE WORKING POINT

... - SOUNDS OF THE WORKSHOP.



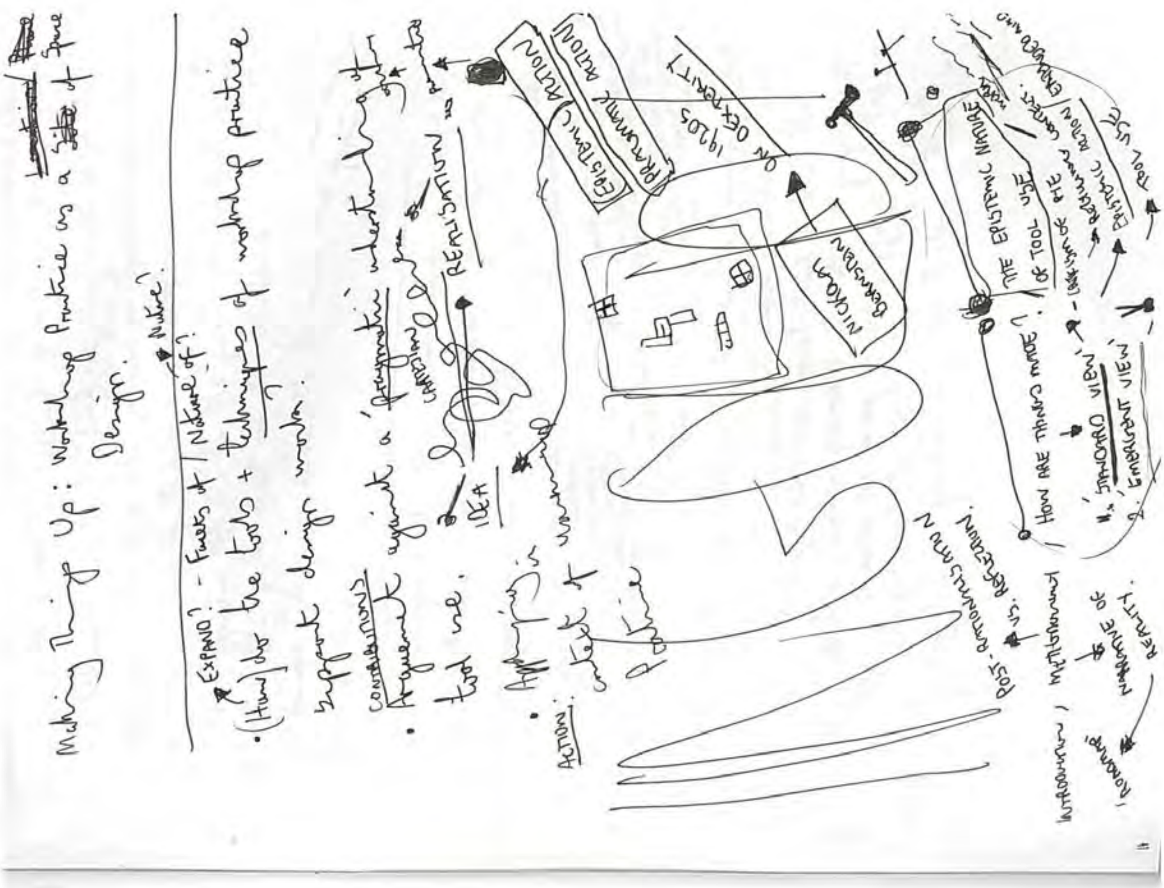
...re is something else to be said here regarding
'steps' of hammering, the way it starts with short
... to set the pin, where there's high risk, moves
longer steps to get the job done (when risk is lower),
returns to shorter steps when the risk rises again (THAT YOU MIGHT DENT/BRUISE THE TIMBER)
... the end. And these steps are contingent upon the
...t of the hammer used. So a more dexterous hammerer might
... to ~~complete the action~~ knock the nail in using fewer
..., satisfied from fewer feedback responses that the task
... going well. Whilst a less experienced hammerer might
... more blows, checking their progress more frequently. These
... of production are ... I'll return to later in this
... 'The Epistemic Potential of alternative techniques'
~~...techniques that Reveal or conceal~~ (Handplane and Thicknesser)
...RT WITH TECHNICAL CHOICE
...will all be 'lower level' stuff, not things ... thought of as design decisions
THERE IS A FIRM GOAL IN MIND
MAIN POINT
It asks questions
Am I set right? Am I going to be right direction? How much longer?
FAIR QUESTION

~~The Epistemic Potential of Material Resistance~~ / These steps are different dimensions

Steps of ~~Tools~~ Making

Ingold asks that we consider making not in terms of steps taken that progress practitioners towards end goals but as 'QUOTE'.
Whilst I find it sympathetic to the hylomorphic model of production, I find the notion of steps in production to be useful and valid. (Keller on heats; Alexander on transformations)

Periods of switching from one process to another, or the pauses between actions in ongoing techniques, offer opportunities for reflection. The physical fact of the emergent artefact not only allows us to ask questions of it, but it raises questions of its own, in the call and response, the dance of agency. Pauses in production of prototypes offer opportunities for these questions to be raised. Keller's study of blacksmithing investigates the the step-based nature of this production context. ~~Blacksmithing~~
The necessity to work with metal ... forces blacksmiths to work in periods of opportunity, between removing a piece of iron from the furnace and returning it once it has become too cold to be worked.
These periods are known as 'heats' and structure the process of blacksmithing. More accomplished smiths can ... making a greater transformation to the metal before it must be reheated. There are always limits to the amount that can be achieved before work must be paused for a


Making Things Up: Workshop Practice as a Site of Space Design.
EXPAND? - Facets of / Nature of?
Nature?
(How) do the tools + techniques of workshop practice support design work?
CONTRIBUTIONS
Argument against a 'pragmatic' understanding of tool use.
IDEA
CARTESIAN
REALISATION
ACTION:
Applying in context of workshop practice
EPISTEMIC ACTION
PRAGMATIC ACTION
1920s
ON DEXTERITY
NICKOLAI BERNSTEIN
POST-RATIONALISATION
VS. REFLECTION.
INTRODUCTION, METHODOLOGY
'ROADMAP'
NARRATIVE OF REALITY.
HOW ARE THINGS MADE?
THE EPISTEMIC NATURE OF TOOL USE
1. 'STANDARD VIEW'
2. 'EMERGENT VIEW'
EPISTEMIC ACTION / EMBODIED MIND
TOOL USE

selecting a hammer

TECHNICAL CHOICES, EXAMPLE OF HAMMER / TECHNICAL CHOICES CAN BE MADE WITH RESPECT TO THE FEEDBACK PROVIDED - THE BEST HAMMER BALANCES EFFICACY WITH FEEDBACK / PURSUIT OF INFORMATION. ; THIS IS IN CONTRAST TO PYE'S PROMOTION OF RESULTS OVER PROCESS.

NO, THIS IS NOT A BALANCE.

I have discussed how tool use is, at a fundamental level, epistemic + pragmatic. I know wish to consider how techniques can be employed in the pursuit of information - PROTO TYPES

~~any way. Whilst pursuing any Throughout~~ During the production ~~any~~ artefact, there are almost always ~~various~~ ~~multiple~~ different techniques ~~through~~ which (potentially) the same outcome may be ~~arrived at.~~ ~~These~~ ~~This presents practitioners with options.~~ ~~Depending~~ on the tools, materials and skills available, ~~to~~ a practitioner must select a course of action - pursuit of their goal ~~so, a choice is made about how to approach a task.~~

~~These~~ choices are ~~entitled~~ termed in ~~texts~~ archaeological literature, ~~is~~ 'technical choices'. ~~*Where these span interest~~ ~~*maximizing the potential motivations for~~ ~~~~~~ ~~, for example, choosing~~

~~setting~~ In what follows, I consider a simple technical choice, between a range of hammers, to knock in a pin. I hope to ~~in order to~~ demonstrate how the previous ~~discussion~~ of dexterity, and ~~the~~ description of ~~the~~ the nature of tool use as ~~simultaneously~~ pragmatic + epistemic ~~nature of tool use~~ ~~illuminate~~ offers a novel theoretical ~~grounding~~ understanding ~~such a decision.~~ From the specifics of hammer use, I go on to discuss how ~~technical choices, and the~~ selection of tools and techniques, more generally, may be considered not ~~just~~ with reference to the efficiency, or in David Pye's ~~terms~~ ~~undoing~~, the ~~one~~ certainty with which they arrive at ~~a~~ pre-determined objective, but by the ways in which they may support epistemic action.

10,12,14

On Selecting a Hammer

~~HAMMERS~~ FEEDBACK + MAXIMUM FORCE

LABLE OZ (FIG

Imagine choosing ~~between~~ ~~one of~~ between three hammers, in order to knock a panel pin into a piece of timber ~~(~~ ~~WRITTEN ABOUT)~~. ~~The~~ All three hammers share the same Warrington head pattern ~~we have~~ studied ~~throughout~~ earlier in this chapter. The difference between them lies in the size and weight of the heads, and the length of their handles. ~~The smaller, 10oz, hammer~~ Whilst ~~all three~~ it would be possible to use any of the three to accomplish our task of knocking in the panel pin, ~~the nature of the~~ ~~been~~ there ~~remains~~ something to be said for the differences in their use. Using the largest, 14oz hammer, it should be possible, with practised technique ~~to drive~~ ~~and owing to its~~ ~~extra~~ ~~greater weight~~, to drive the pin home using fewer blows than with the 10oz version. Owing to its greater weight, the 14oz hammer has the potential to deliver a more forceful strike. Exaggerating this distinction... P.T.

~~This more forceful strike, however, increases the demands on our dexterity, or our sensitivity to the feedback of the hammer as an instrument for reporting on the progress of a task. If this force were to delivered~~ ~~100%~~ ~~accurately~~, by ~~means of a machine or jig, the greater force would be.~~

But, in order to deliver this blow accurately, without bending the pin or slipping off of its head, ~~this extra~~ the ~~heavier~~ hammer must still provide a good degree

- coupling of perception and action during skilled tool makes the two components ~~separable~~ inseparable.

y are selected according to both the speed with which can complete a task and the quality of feedback they . This a decision not based upon the properties of the er in isolation, but with consideration to how those ties will operate as part of a system including the material and practitioner

THE ISSUE THEN IS 'WHAT TO LOOK FOR?' DURING THOSE OPPORTUNITIES FOR REVISION ETC. THE NEXT CHAPTER SCALES THIS UP, FROM LEVEL OF TOOL-USE TO DESIGN PROJECTS. - STEP-BY-STEP

*

*

IIQUES MAY BE
NIC IN THE FOLLOWING WAYS

n about properties of material at it can and can't do)

*

This is the most important one for the next chapter

1. Check progress of the action (opportunity for revision + correction) learning about behaviour with ... in the hammer example

This influences the nature of the process - tends towards diversity

Maybe make more of this at the end of the hammer drawing

*

*

*

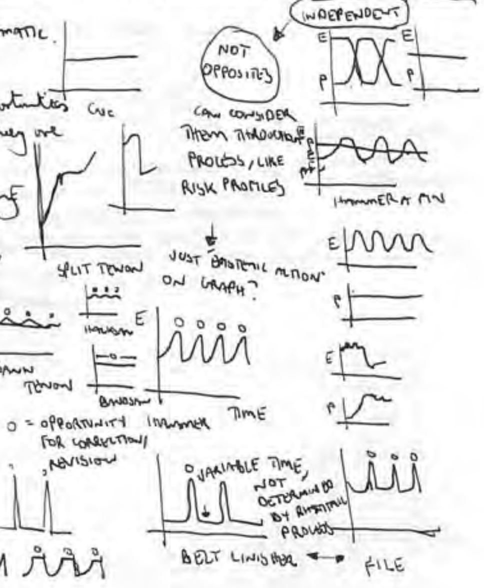
PART 5 Risk, Certainty and Epistemic Potential

Are ~~x~~ riskier processes the same as those which have a greater epistemic potential? - SEE PICTURES ABOVE Are certain processes more pragmatic? - EPISTEMIC WORKMANSHIP + PRAGMATIC WORKMANSHIP

↳ YES. + DIGITAL FAB. IS ENTIRELY PRAGMATIC.

· Both sawn + split tenons offer opportunities for revision + correction. But they are different in learning about the material. The epistemic opportunity is regarding learning about the behaviour of the wood. In the filing vs. limiting example, the difference is in the opportunity for revision + correction.

↳ Maybe I should split these up



...L ACTION AT LEVEL OF SOME ... AS A METHOD OF FINDING OUT ABOUT BEHAVIOUR OF THE WORLD —
...N OPPORTUNITY FOR REVISION + CORRECTION. + SOMETHING ABOUT 'JIG-FREE' REVISION WITH DEXTERITY — MAYBE IN SUMMARY

. nature of skilled practice / tool use requires tools to simultaneously ... support both pragmatic + epistemic action. They are ... for doing things and also instruments for sensing ... those things are going. With every strike of ... hammer, we drive the pin ~~being driven~~ further into ... timber, but also develop an improved understanding of ... well the task is going, through the feedback.

...WITH CHOOSING A HAMMER? OR AT LEAST A ...ITIPLE STRIKES ASSOCIATED WITH HAMMERING. BIT ABOUT HAMMERING
...ORTUNITY TO LEARN ABOUT THE (BEHAVIOUR OF THE) WORLD, AND REVISE THE APPROACH

... IN WHAT FOLLOWS, I ~~CONSIDER~~ INVESTIGATE/EXPLORE THE EPISTEMIC POTENTIAL OF VARIOUS ...ELY. TECHNIQUES, JUST AS A HAMMER IS SELECTED/USED TO TASK, WITH REF. TO IT'S PRAGMATIC + EPISTEMIC EFFECTS, I ...E TECHNIQUE CHOICES WITH VARYING DEGREES OF EPISTEMIC POTENTIAL/WITH EXAMPLE OF EPISTEMIC CHARACTER

. ~~MAKE~~ DISCUSS HOW VARYING TECHNIQUES HAVE DIFFERENT CHARACTERS THAT AFFECT THIS
↳ EVEN THOUGH THEY CAN ACHIEVE THE SAME RESULT.
↳ HOW THE NEXT CHAPTER PLUGS THIS INTO THE DESIGN PHASE.

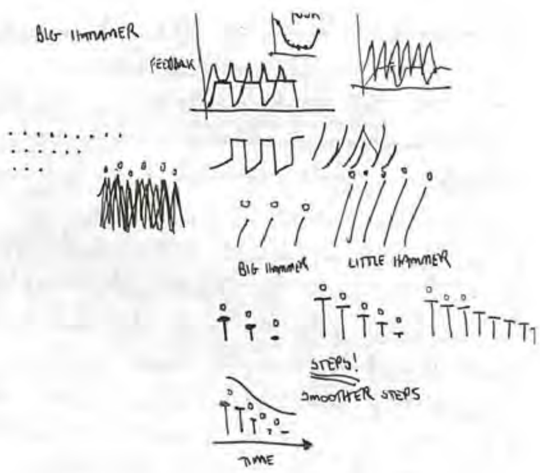
...E GRAPHS TO DO THIS.

OBJECTS (TOOLS, TECHNIQUES) CAN BE CONSIDERED IN TERMS OF HOW THE PROCESS SUPPORTS OPPORTUNITIES FOR LEARNING + REVISION.

...OSER	+	HAND PLANE
...ER	+	HAND FILE
...TENON	+	SPLIT TENON
...SAW	+	CHOP SAW

MAYBE SHOULD DESCRIBE HOW THERE ARE PIECES OF EQUIPMENT, eg. METAL LATHE, WITHOUT WHICH IT WOULD BE ALL BUT IMPOSSIBLE TO ACHIEVE CERTAIN RESULTS, BUT THERE ARE STILL DIFFERENT APPROACHES WHILST USING THOSE MACHINES/ WHICH MIGHT HAVE DIFFERENT EPISTEMIC CHARACTERS

RHYTHMANALYSIS



▸ E.G. Dexterous processes may enable quick revisions, for the purpose of epistemic action. Dexterity is not only developed to achieve pragmatic results, but to work skilfully in the world.

Last Chapter

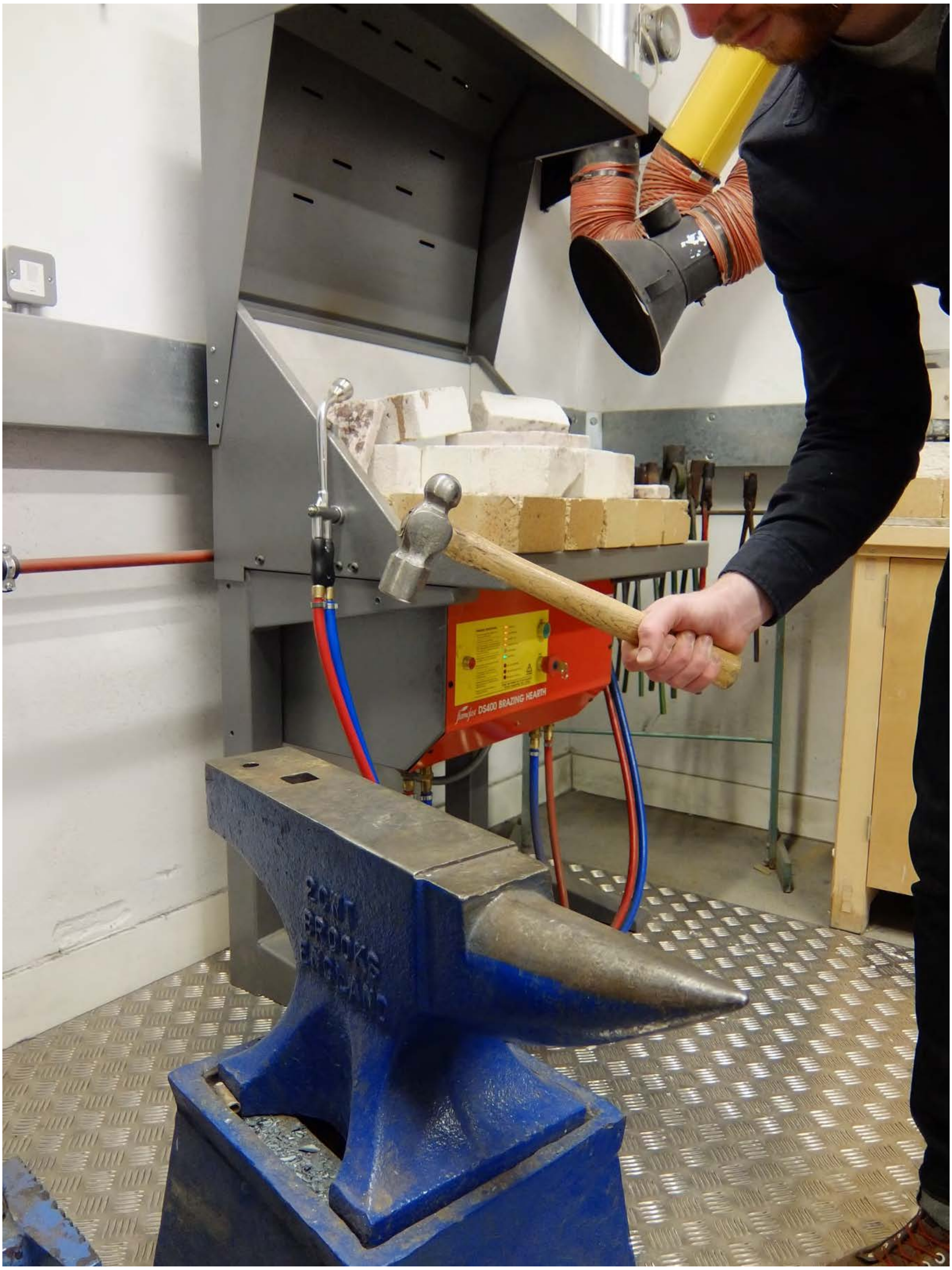
. Critique of Pye; Epistemic action + the extended mind; Tool use is epistemic + pragmatic; Tools and techniques may be ~~considered~~ dimensional according to their epistemic nature · ASKS QUESTIONS (PICKERING'S DANCE) → SOME PROCESSES ASK MORE THAN OTHERS
↳ NEXT CHAPTER TALKS ABOUT SEQUENCE OF QUESTIONS.

PYE → 'DIVERSITY' — THE QUALITIES OF THE OUTCOME IS AFFECTED, THAT'S WHY THIS IS SIGNIFICANT — THE 'RIPENING OF AN IDEA'.

This Chapter ~~has~~ began by introducing David Pye's writing on workmanship + design. Focused as it is on ... to pre-determined objectives, I criticised Pye's ~~...~~ pragmatic understanding of production. The notion of epistemic action ~~and~~ has, I hope to have demonstrated, provided a novel and useful understanding of production. ~~...~~ Where Pye stressed the importance of results over ~~the~~ what he would consider illogical ... of the value of one technical choice over another, I have attempted to provide a means of analysis that is complementary, rather than opposed to his work. If techniques of production may

3. A selection of photographs used as a basis for the line drawings

Reference photograph for Figure 4.1 ‘Setting a pin using a Warrington pattern hammer’

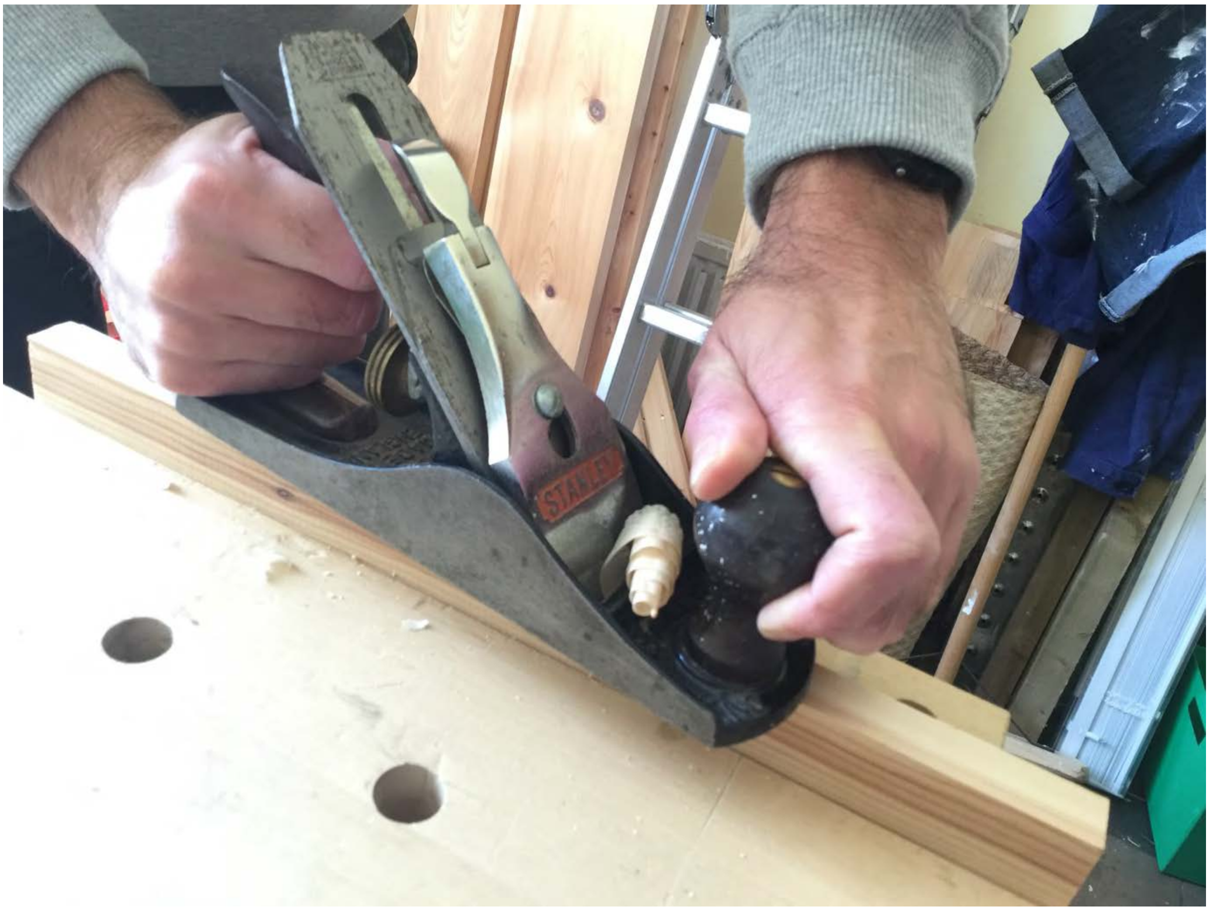


Reference photograph for Figure 4.11 ‘The trajectory of a blacksmith's swing’

Reference photograph for Figure 6.15 ‘Using a taper tenon cutter’

Reference photograph for Figure 5.28 ‘Carving with a hook knife’

Reference photograph for Figure 5.25 ‘A test split to check the run of the grain’



Reference photograph for Figure 6.9 ‘Using a bench plane’